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REVISION OF THE AMPHIBIA AND PISCES

OF THE

PERMIAN OF NORTH AMERICA

By

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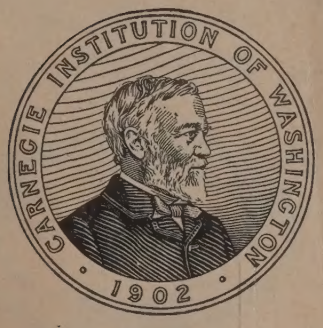
WITH A

Description of Permian Insects by E. H. Sellards

AND A

Discussion of the Fossil Fishes by Louis Hussakof



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PREFACE.

This volume forms the third of the series dealing with the vertebrates of the Permian or Permo-Carboniferous of North America. The author hopes that the publication of these volumes has, in a large degree, cleared up the synonymy and corrected the unavoidable errors of the earlier writers and has laid a more secure foundation for the study of the primitive life of the time. The object of the publication has not only been to describe the morphology of the forms, but to prepare a basis for the study of their evolution and distribution, which will contribute to an understanding of the physical conditions and paleogeography of the closing portion of the Paleozoic. The work will be continued on these lines.

It is necessary, and most pleasant, to repeat my thanks to the Carnegie Institution of Washington for the aid which has made the preparation of these volumes possible; to the authorities of the American Museum of Natural History in New York, and to those of other institutions in this country and Europe who have most generously placed material at my disposal.

My thanks are especially due to Doctors Williston, Matthews, Broom, and Broili for valuable advice and criticism; to Dr. Louis Hussakof, whose contribution on the Fossil Fishes is an independent piece of work of the greatest value; to Dr. E. H. Sellards, who has described two new fossil cockroaches.

Finally, I desire to thank Messrs. Christman and Thompson, of the American Museum, for the skill and care with which they have prepared many of the drawings and photographs in this and the preceding monographs.

E. C. Case.

November 30, 1910.

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REVISION OF THE AMPHIBIA AND PISCES

OF THE

PERMIAN OF NORTH AMERICA

HISTORICAL REVIEW.

The first mention of Permian vertebrates in North America occurs in a description by Cope (20) of a small collection of fossils made by Dr. J. C. Winslow, in the vicinity of Danville, Illinois. Cope identified four forms, a Pelycosaur *Clepsydrops colleti*, an amphibian *Cricotus heteroclitus* (regarded by him at the time as a rhyncocephalian reptile related to *Clepsydrops*), and two fishes, a dipnoan *Ceratodus vinslovii*, and a shark *Diplodus* sp. The beds from which these fossils were obtained were regarded as belonging to the Triassic or Permian age, "since on the one hand *Reptilia* have not been found in the coal measures, nor on the other hand has the genus *Diplodus* been found above the Carboniferous series of rocks."

A second lot of fossils sent to Cope by Dr. Winslow and a lot obtained by Mr. William Gurley permitted him to extend his observations and descriptions (21). In this paper Cope mentioned or described as new:

Strigilina linguæformis gen. et sp. nov. *Petalodontidarum.*
Selachii:
Diplodus (?) *compressus* Newberry.
Dipnoi:
Ceratodus vinslovii.
Ceratodus paucicristatus.
Ctenodus fossatus.
Ctenodus gurleyanus.
Crossopterygia:
Peplorhina arctata.
Amphibia:
Cricotus heteroclitus.

A renewed consideration of the fauna confirmed Cope in his previous idea as to the age of the beds: "The present fauna must then be placed above the Coal Measures, and the horizon will correspond more nearly with the Permian than with any other embraced in the system." The position is reported on the authority of Dr. Winslow to be near the top of the Coal Measures and to be marked No. 15 in Prof. F. H. Bradley's section of the "Coal Measures of Vermilion County, Illinois" (Geol. Survey, Illinois, vol. IV, p. 245).

Later in the same year Cope (22) added to the list of animals from the Permian of Illinois:

Amphibia:
Cricotus gibsoni.
Cricotus discophorus.
Lysorophus tricarinatus.
Diplocaulus salamandroides.
Eryops megacephalus.

Fishes:
Strigilina gurleiana.
Ctenodus pusillus.
Orthacanthus quadriseriatus.

It is suggested here that *Orthacanthus* and *Diplodus* may be synonymous. The two species *Ceratodus gurleianus* and *C. paucicristatus* are referred to a new genus, *Ptyanodus*.

In this same paper Cope remarks that he is informed that Professor Bradley's layer No. 15 occupies a higher position than was assigned to it and that it lies unconformably above the Merom sandstone, which lies above the Coal Measures and is unconformable with them. This confirmed Cope in his reference of the bone-bearing beds, his *Clepsydrops* shales, to the Permian. As will be shown below, the position of these beds is still very much in doubt.

In 1878, in his first contribution to the history of Permian fauna of Texas (23), Cope reported the following new amphibians:

Epicordylus erythroliticus.	*Zatrachys serratus.*
Eryops megacephalus.	*Trimerorhachis insignis.*
Parioxys ferricolus.	*Rachitomus valens.*

Epicordylus, which was founded on the caudal vertebræ of *Eryops*, as later recognized by Cope, was here regarded as a reptile.

Parioxys was placed in the suborder *Labyrinthodontia*, and *Trimerorhachis* and *Rachitomus* in the *Ganocephala*. *Rachitomus* was founded on vertebræ of *Eryops*. Two humeri, without entepicondylar foramina, Nos. 5 and 6, are referred to the *Pelycosauria;* these evidently belong to the genus *Eryops*.

Three new dipnoans are named in the same paper, *Ctenodus periprion*, *C. porrectus*, and *C. dialophus*.

Cope here correlates his *Clepsydrops* shales of Illinois with the Texas beds and reasserts the reference of both to the Permian. "The evidence now adduced is sufficient to assign the formation, as represented in Illinois and Texas, to the Permian. Besides the saurian genera above mentioned, the existence of the icthyic genera *Janassa*, *Ctenodus*, and *Diplodus*, in both localities, renders this necessary."

In 1878, Marsh (60) described in the "American Journal of Science" some fossils from New Mexico, naming as new *Ophiacodon mirus* and *O. grandis* from very fragmentary remains. They were regarded as reptiles, but are clearly amphibians of uncertain relationships.

In 1880, in the "American Naturalist" (24), Cope referred *Eryops*, *Rhachitomus*, *Trimerorhachis*, and probably *Actinodon* of Gaudry, to the *Ganocephala*, because they possessed distinct intercentra and centra, the *Labyrinthodontia* having the vertebra solid.

In a more extended paper before the American Philosophical Society, in the same year (26), Cope reviewed Owen's suborder *Ganocephala*, and after concluding that the definition was inadequate he offered a new definition of the group, as follows:

"Vertebræ consisting of centra and intercentra, the former not extending to the base of the vertebra, the latter not rising to the neural canal. The centrum consisting of two parts distinct from the superior neural arch; viz, a lateral piece (pleurocentrum), on each side. Atlas consisting of separate seg-

ments, the superior of which are not united above the neural canal, and the inferior (intercentrum), divided on the middle line into two segments.

"*Genera: A*, Basioccipital bone without condyles: *Trimerorhachis* Cope; *Archegosaurus* v. Meyer. *A.A*, Basioccipital condyles two: *Actinodon* Gaudry; *Rhachitomus* Cope; *Eryops* Cope.

"All the above genera have well-developed neural spines except *Trimerorhachis*."

In the same paper was described as new, *Ectosteorhachis nitidus*. This was classified as "Tribe *Crossopterygia;* family *Rhombodipteridæ* Traquair; subfamily *Saurodipterini* Huxley."

In the "American Naturalist" for 1880 (27), in a comment on Fritsch's "Fauna der Gaskohle und der Kalksteine der Performation Böehms," Cope suggests the formation of a new suborder to contain the genus *Cricotus*, which he calls *Embolomera* and defines as follows: "Centra and intercentra subequally developed as vertebral bodies, a single neural arch supported by one of each, forming a double body. Chevron bones supported only by intercentra. Basioccipital vertebral articulation cup-like, connected with the first vertebra by an undivided discoid intercentrum.

"Thus the peculiarity of the vertebral column in general is carried into the cephalic articulation, and we have, instead of the complex articulation of the *Ganocephala*, a single body connecting the occipital condyle and the first vertebra. This body represents, in all probability, the *single occipital condyle of the Reptilian skull*. This part, as is well known, remains cartilaginous in the lizard long after the basioccipital is ossified, and is a distinct element. The structure of *Cricotus* shows that it is a connate intercentrum. We have now removed the last difficulty in the way of the proposition that the Reptilia are derivatives of the *Batrachia*, viz, the difference in the craniovertebral articulation. But the former have not been derived from the *Labyrinthodontia* as has been suggested, nor from the *Ganocephala*, but from the *Embolomera*, as I shall call the new order, or suborder. The order of *Reptilia* which stands next to it is, of course, the *Theromorpha*, which presents so many Batrachian characters, including intercentra, as I have for the first time pointed out in the paper above quoted. Besides *Cricotus*, Fritsch describes a genus from Bohemia under the name *Diplovertebron*, which I suspect to belong to the *Embolomera*."

In 1881, in "Bulletin of the U. S. Geological and Geographical Survey of the Territories" (27), Cope described *Pantylus cordatus* as an amphibian; this he corrected later (30).

In February of 1881 Cope published his first catalogue of the vertebrata of the Permian formation of the United States (28), including:

Pisces:
Crossopterygia:
Ectosteorhachis nitidus.
Dipnoi:
Ctenodus fossatus, C. gurleianus, C. periprion, C. porrectus, C. dialophus, C. pusillus, Ptyanodus vinslovii, P. paucicristatus.

PISCES—continued.
Selachii:
Janassa gurleiana, J. strigilina, J. ordiana.
Diplodus (?) compressus, D. sp.
Orthacanthus gracilis, O. quadriseriatus.
BATRACHIA:
Stegocephali:
Ganocephala:
Eryops megacephalus, Trimerorhachis insignis, Zatrachys serratus, Parioxys ferricolus, Pantylus cordatus.
EMBOLOMERA:
Cricotus heteroclitus, C. gibsoni.

Lysorophus tricarinatus was listed in the family *Clepsydropidæ*, and *Diplocaulus* in a new family *Diplocaulidæ*, both under the *Pelycosauria.*

In the "American Naturalist" for December of 1881 (29), Cope described from the Permian deposits of New Mexico *Eryops reticulatus* and *Zatrachys apicalis.*

In the "American Naturalist," 1882, page 335 (30), Cope corrects the previous reference of *Eryops*, *Trimerorhachis*, and *Rhachitomus* to the *Ganocephala.* They were placed in that order because Cope believed *Archegosaurus* to have rhachitomus vertebræ, but as it was shown by Fritsch that *Archegosaurus* has discoidal vertebræ, the old group must be abandoned and a new substituted. He proposed a new suborder, *Rhachitomi*, which he divided into two families:

Occipital condyle concave, undivided.....*Trimerorhachidæ*
Occipital condyle divided into two lateral condyles.....*Eryopidæ*

The first family included *Trimerorhachis* only, the second, *? Parioxys, Eryops, Actinodon, Zatrachys, ? Pantylus.*

In a more extended article in the "Proceedings of the American Philosophical Society," a little later in the same year (31), he described as new *Acheloma cumminsi* and *Anisodexis imbricarius*, which he placed in the order *Rhachitomi:* family *Eryopidæ.* He listed as members of this family:

Anisodexis imbricarius.
Acheloma cumminsi.
Eryops reticulatus.
Eryops ferricolus (Parioxys olim).
Eryops megacephalus.
Actinodon trossardi.
Zatrachys serratus.
Zatrachys apicalis.

The occipital condyles of *Acheloma* and *Zatrachys* were unknown to him and so the genera were included provisionally. In a note to this paper it is stated that *Peplorhina arctata* is not a fish, but a Theromorph Saurian (Pelycosaur). See a later note by Case (11).

The genus *Diplocaulus* was recognized as an amphibian and placed in the suborder *Microsauria.*

In 1883, in the fourth contribution to the history of the Permian formation of Texas (32), Cope described *Trimerorhachis bilobatus* and the fishes *Ectosteorhachis ciceronius* and *Gnathorhiza serrata.*

In the "Proceedings of the Philadelphia Academy of Natural Science" (33), Cope substituted the name *Didymodus* for *Diplodus*, as the latter name was preoccupied, and named several new fishes: *Thoracodus emydinus*, *Ctenodus heterolophus*, and *Ctenodus vabasensis*.

Following this paper came one in the "Proceedings of the American Philosophical Society" (34), in which Cope described and figured the skull of the genus. This paper was preceded by two brief notes in the "American Naturalist" giving preliminary accounts of the skull (35, 36). The use of the name *Didymodus* by Cope provoked a discussion with Dr. Gill in the columns of "Science" (vol. III, pp. 275, 429, 645), but Cope did not alter the name.

In the first of these papers Cope proposed a new order of the *Elasmobranchii* to contain *Didymodus*, which he called *Icthyotomi* and defined as follows:

"A basioccipital bone and condyle. Occipital, (?) pterotic, and frontal bones distinct. Supraorbital (or nasal) bones present."

The remaining members of the *Elasmobranchii* were distinguished as a separate group by the want of these characters and called by the old name *Selachii*.

Garman engaged in a discussion with Cope and published several short papers in "Science" during 1884 and 1885, protesting against Cope's proposition that *Didymodus* was identical with or closely related to the *Chlamydoselachi*. The most important and culminating paper was printed in the "Bulletin of the Museum of Comparative Zoology" in 1885 (53). In this he insisted that the two forms are not related and proposed a new name *Diacranodus* for the Permian shark. He defines his genus as "distinguished by the attachment of the pterygoquadrate to the postorbital process of the cranium, and by the teeth; cusps two, diverging, subconical, slender, and separated by a median rudimentary denticle or button on the base; bases extending backward, thinner and rounded posteriorly."

Cope replied to this in the "American Naturalist," criticizing Garman and retaining the name *Didymodus* (40).

In the "American Naturalist," Jan. 1884, Cope published a semi-popular account of "The Batrachia of the Permian Period of North America" (37); in this he gave a genealogical table of the class *Batrachia* and an analysis of the characters of the Permian forms as follows:

"1. Supraoccipital, intercalary (tabulare) and supratemporal (squamosal) bones present. Propodial bones distinct.
Vertebral centra, including the atlas, segmented, one set of segments together supporting one arch.....*Rhachitomi*
Vertebræ segmented, the superior and inferior segments each complete, forming two centra to each arch.....*Embolomeri*
Vertebral centra, including atlas, not segmented; one to each arch....*Stegocephali*

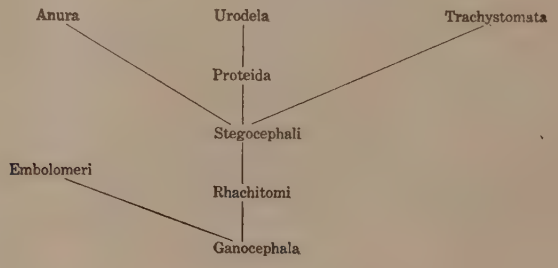
"As regards the extinct orders, the primitive type is evidently the *Rhachitomi* whose vertebral column displays an arrest of characters which are transitional in the higher Vertebrata. From this group the orders *Embo-*

lomeri and *Stegocephali* have evidently been derived. We may then present the following genealogical table of the class Batrachia:

Cope placed in the *Rhachitomi*, the genera *Trimerorhachis*, *Eryops*, *Acheloma*, *Anisodexis*, and *Zatrachys*. In the *Embolomeri* he put the single genus *Cricotus*.

In the latter part of 1884 appeared the "Fifth Contribution to the knowledge of the Fauna of the Permian Formation of Texas and the Indian Territory" (38). In this paper Cope named a new species of Dipnoan, *Ceratodus favosus*, and two species of the genera *Cricotus*, *C. crassidiscus* and *C. hypantricus*. With the former he identifies the specimens of *C. heteroclitus*, named and described in 1880 (25) and 1884 (37). In the first paper figures *a* and *b* of plate 11, and in the second paper figures *a*, *b*, *c*, and *d* of plate 5, are regarded as representing the species *crassidiscus* and figures *f* and *g* of the same plate, in the second paper, the species *heteroclitus*.

In 1885 came Cope's discussion "On the Evolution of the Vertebrata, Progressive and Retrogressive" (39); in this he repeated the analytical key of the Permian amphibians, but slightly changed his ideas of the phylogenetic relations, as is shown in the following diagram:



The *Rhachitomi* are held to contain the *Eryopidæ*, and the *Ganocephala* the *Trimerorhachidæ* and *Archegosauridæ*.

In May of 1886, Cope read before the American Philosophical Society a catalogue of the Permian Vertebrates of North America (41). This was published as a separate in the same year, but the volume of the Transactions of the Society in which it appeared was not completed until 1888. In this paper he gives the following list and arrangement of the fishes and amphibians:

PISCES.

SELACHII.

Thoracodus emydinus.
Janassa.
J. strigilina.
J. gurleiana.
J. ordiana.
Orthacanthus.
O. gracilis.
O. quadriseriatus.
Didymodus.
D. texensis.
D. platypternus.

DIPNOI.

Ctenodus.
C. fossatus.
C. gurleianus.
C. periprion.
C. porrectus.
C. vabasensis.
C. dialophus.
C. pusillus.
Ptyanodus.
P. vinslovii.
P. paucicristatus.
Gnathorhiza serrata.
Ceratodus favosus.

TELEOSTOMI.

Ectosteorhachis.
E. nitidus.
E. ciceronius.

BATRACHIA.

GANOCEPHALA.

Trimerorhachis.
T. insignis.
T. bilobatus.

RHACHITOMI.

Zatrachys.
Z. serratus.
Z. apicalis.
Eryops.
E. megacephalus.
E. erythroliticus.
E. ferricolus.
E. reticulatus.
Acheloma cumminsi.
Ansiodexis imbricarius.

STEGOCEPHALI.

Diplocaulus.
D. salamandroides.
D. magnicornis.

EMBOLOMERI.

Cricotus.
C. heteroclitus.
C. gibsoni.
C. crassidiscus.
C. hypantricus.

A front foot, previously described as *Icthycanthus platypus* (Proc. Am. Phil. Soc., 1877, p. 54), was in this paper referred to the genus *Eryops*. This reference is exceedingly doubtful.

In 1887 appeared that portion of Zittel's Handbuch d. Paleontologie, dealing with the more primitive fishes. The following disposition is made for the Permian fish:

Subclass *Selachii*.
Suborder *Plagiostomi*.
Family *Xenacanthidæ*.
Genus *Didymodus*.
Orthacanthus.
Suborder *Batoidei*.
Family *Petalodontidæ*.
Genus *Janassa*.
Thoracodus.

Subclass *Dipnoi*.
Order *Ctenodipterini*.
Genus *Ctenodus*.
Ptyanodus.
Gnathorihiza.
Strigilina.
Order *Sirenoidea*.
Genus *Ceratodus*.

Subclass *Ganoidei*.
Order *Crossopterygidæ*.
Family *Rhombodipterini*.
Genus *Ectosteorhachis*.

In 1888 appeared the portion dealing with the *Amphibia*.

Diplocaulus is placed as uncertain, in the family *Microsauria* of the suborder *Lepospondyli*. The others are arranged as follows:

Suborder *Temnospondyli*.
Division A. Rhachitomus vertebræ.
Genus *Trimerorhachis*.
Eryops (*Rhachitomus*).
Epicordylus (*Parioxys*).
Zatrachys.
Acheloma.
Anisodexis.
Division B. Embolomerous vertebræ.
Genus *Cricotus*.

In 1889 Cope published a synopsis of the families of the vertebrates (42). In this he divides the *Elasmobranchii* into two orders, which he defines as follows:

"A basioccipital and exoccipital elements; actinotrichia; baseosts and axonosts continuous with neural spines; paired fins with a single basal axonost, and numerous others in line with it; claspers simple.....*Icthyotomi*
No basi- or exoccipital; median baseosts and axonosts continuous with vertebral spines; several axonosts to paired fins, and numerous baseosts; claspers complex; actinotrichia.....*Selachii*"

In the first order was placed the *Xenacanthidæ*, including the Permian *Diacranodus* and the *Cladodontidæ*. In the second order were placed all the other families of the sharks.

The *Stegocephali* was divided into the orders *Ganocephali*, with the families *Trimerorhachidæ* and *Archegosauridæ*, the former without and the latter with neural spines on the vertebræ; the *Rhachitomi* with a single family, the *Eryopidæ*, in which is included the *Labyrinthodontia;* the *Embolomeri*, with the single family *Cricotidæ;* and the *Microsauria* with the families *Branchiosauridæ*, *Hylonomidæ*, *Molgophidæ*, *Phlegethontiidæ*.

His synopsis of characters is as follows:

"Subclass *Stegocephali*. Basioccipital, supraoccipital, intercalare, and supratemporal bones present; propodial bones distinct.
a. One occipital articulation.
Vertebral bodies represented by basal and lateral elements (intercentra and centra).....*Ganocephali*
aa. Two lateral occipital condyles.
Vertebræ represented by distinct and incomplete intercentra and centra (pleurocentra); atlas segmented.....*Rhachitomi*
Centra and intercentra complete, making two vertebral bodies to each neural arch.....*Embolomeri*
No centra; intercentra each supporting a neural arch.....*Microsauri*"

Smith-Woodward in the "Catalogue of Fossil Fishes in the British Museum" (74) substituted *Pleuracanthus* for Cope's *Didymodus*. He gives:

Subclass *Elasmobranchii*.
Order *Selachii*.
Family
Genus *Pleuracanthus*.
Family *Petalodontidæ*.
Genus *Janassa*.
Genus *Thoracodus*.

Subclass *Dipnoi*.
Order *Sirenoidæ*.
Family *Lepidosirenidæ*.
Genus *Ceratodus*.
Family *Ctenodontidæ*.
Genus *Sagenodus* (*Ptyanodus*).

Subclass *Teleostomi*.
Order *Crossopterygia*.
Family *Osteolepidæ*.
Genus *Megalicthys* (*Ectosteorhachis*).

In the "Catalogue of the Fossil Reptilia and Amphibia of the British Museum (N. H.), 1890," Lydekker (59) gives the following classification of the Permian *Amphibia* from North America:

Order *Labyrinthodontia.*
Suborder *Labyrinthodontia vera.*
Family *Diplospondylidæ.*
Genus *Cricotus.*
Family *Archegosauridæ.*
Genus *Trimerorhachis.*
Family uncertain.
Eryops (*Rhachitomus*, *Epicordylus*, *Parioxys*).

In 1890 Lydekker (**58**) described a lower jaw and an intercentrum from the Karroo system of South Africa, which he referred provisionally to *Eryops*. There is no doubt that these specimens belong to a totally different genus from *Eryops;* the only resemblance between the two consists in characters common to all the primitive *Temnospondyli*. The specimens were referred to as *E. oweni* in the "Quarterly Journal of the Geological Society," but later, in the "Catalogue of the Fossil Reptiles and Amphibians of the British Museum," the species is called *E. africanus*.

Gadow in 1896 (**51**) proposed that the genera *Eryops* and *Cricotus* be placed among the *Reptilia*, and, later, in 1901, in "The Cambridge Natural History" (**52**), he formed the subclass *Proreptilia* to receive them. This proposition was based on the conclusion that the vertebræ of these forms are gastrocentrous in origin, an idea which has not been generally accepted.

In 1895 Cope described a new amphibian with a distinct carapace of transverse plates as *Dissorhophus multicinctus* (**43**). He later spoke of this form as a new genus of *Ganocephalous Stegocephali* (**47**).

In 1896 Cope published in the "Proceedings of the American Philosophical Society" the first of two papers on the "Paleozoic Reptilian order Cotylosauria" (**45**); this was preceded by an abstract published in the "American Naturalist" (**44**). In these papers there were described as new: *Zatrachys micropthalmus*, *Z. conchigerus*, *Trimerorhachis mesops*, *Diplocaulus limbatus*.

In the "American Naturalist" of the same year (**46**) he described a new family *Otocœlidæ* with two genera *Otocœlus* and *Conodectes*, which he referred to the *Reptilia*. As shown in the body of this paper the first genus is an amphibian and the name is synonymous with *Dissorhophus;* the second is probably identical with *Seymouria*, a Cotylosaur. This paper and a second in the November "Naturalist" (**47**) were in part a preliminary of his "Second Contribution to the History of the Cotylosauria" (**48**). In the Second Contribution he named one new species of *Trimerorhachis*, *T. conangulus*.

In 1897 Williston reported the occurrence of Permian vertebrates from Cowley County, Kansas (**67**, **68**).

In the second edition of his lectures on the Vertebrates, published in 1898, after his death (**49**), Cope adopted the new order of *Elasmobranchs* proposed by Smith-Woodward, so his divisions are *Acanthodii*, *Icthyotomi*, and *Selachii*. The classification of the *Pisces* and *Amphibia* is otherwise unchanged.

In 1899 appeared a description of the genus *Dimetrodon* by Baur and Case; in this the genus *Ophiacodon*, considered by Marsh as a reptile, was referred to the *Amphibia* (1).

In 1900 Case undertook a redescription of the vertebrates from Illinois (11) and the bones from this locality were figured in his paper for the first time. No new forms were described, but the genus *Peplorhina*, abandoned by Cope, was re-established.

Two years later (12) the same author described more fully the vertebræ of *Lysorophus tricarinatus;* they were still regarded as reptilian.

In 1902, Hay's "Catalogue of the Fossil Vertebrates of North America" appeared as Bulletin 179 of the U. S. Geological Survey (54). His classification of the fish and *Amphibia* is as follows:

Class *Elasmobranchii.*
Subclass *Plagiostomata.*
Superorder *Icthyotomi.*
Family *Pleuracanthidæ.*
Genus *Diacranodus* (*Diplodus*).
Pleuracanthus.
Orthacanthus.
Superorder *Euselachii.*
Family *Petalodontidæ.*
Genus *Janassa.*
Thoracodus.
Icthyodorulites.
Ctenacanthus.

Class *Pisces.*
Subclass *Azygostei.*
Superorder *Dipnoi.*
Order *Sirenodei.*
Family *Ctenodontidæ.*
Genus *Sagenodus* (*Ctenodus, Ptyanodus*).
Gnathorhiza.
Family *Ceratodontidæ.*
Genus *Ceratodus.*

Class *Pisces*—continued.
Subclass *Teleostomi.*
Superorder *Rhipidistia.*
Family *Osteolepidæ.*
Genus *Parabatrachus* (*Ectosteorhachis*).
Superorder *Actinopteri.*
Order *Chondrostei.*
Family *Platysomidæ.*
Genus *Platysomus.*

Class *Batrachia.*
Suborder *Microsauria.*
Family *Diplocaulidæ.*
Genus *Diplocaulus.*
Suborder *Apœcospondyli.*
Family *Archegosauridæ.*
Genus *Trimerorhachis.*
Dissorophus.
Family *Cricotidæ.*
Genus *Cricotus.*
Family *Eryopidæ.*
Genus *Eryops* (*Parioxys, Rhachitomus, Epicordylus*).
Anisodexis.
Acheloma.

In 1902 (4) Broili published a preliminary account of the skull of *Diplocaulus*, in which he proposes to renew the family *Diplocaulidæ* and place it in the *Amphibia* where it belongs, considering that Cope had not made the correction. He proposes as a classification:

Lepospondyli.
Family *Microsauridæ* Dawson.
Aistopodidæ Miall.
Diplocaulidæ nom. nov.

In 1903 Case described a new species of *Eryops*, *E. latus*, and a species of *Zatrachys*, *Z. crucifer* (14).

The same year he described a collection of fossils found in northern Oklahoma (15). There were reported from this locality:

PISCES.

Elasmobranchii.
Diacranodus (*Pleuracanthus*) *compressus* Cope.
Dipnoi.
Sagenodus (*?*) sp.
Diplocaulus magnicornis, *D. limbatus*, *D. salamandroides.*
Trimerorhachis leptorhynchus sp. nov.
Cricotus sp.
Cricotillus brachydens gen. et sp. nov.
Eryops megacephalus.
Crossotelos annulatus gen. et sp. nov.

In 1904 Broili published his paper on Permian reptiles and Amphibians of Texas in the "Paleontographica" (5). Several new forms were described as listed below:

Order *Stegocephali.*
Suborder *Lepospondyli.*
Family *Diplocaulidæ.*
Genus *Diplocaulus.*
D. copei nov.
D. pusillus nov.
Suborder *Temnospondyli.*
Genus *Cricotus.*
Trimerorhachis.
Eryops.
Zatrachys.
Acheloma.
Anisodexis.
Dissorophus.
Aspidosaurus nov.
A. chiton nov.
Cardiocephalus nov.
C. sternbergi nov.

Lysorophus and *Otocœlus* are regarded as reptiles. The first is placed in a new family *Paterosauridæ* and regarded provisionally as *Rhyncocephalian.*

Later in the same year (6) a second paper by Broili elaborated the idea of the fundamental position of *Lysorophus* and suggested that there must be a diphyletic origin of the *Reptilia*, one branch passing back through the *Cotylosauria* to the *Stegocephalia* and another through the *Paterosauridæ* to the fish.

Another paper (7) describes the skull of the Permian shark, to which Broili gives Garman's name *Diacranodus.* The species *platypternus* is regarded as a synonym of *D. texensis.*

In 1907 Case described as *Zatrachys apicalis* a fossil from Texas (16). And the next year he gave an account of the skull of *Lysorophus*, referring the genus to the *Amphibia* (17). This paper was answered by Broili (8) who reasserted the reptilian character of *Lysorophus*, but he now regarded it

as a *Lacertilian*, instead of a *Rhyncocephalian*, and closely related in habits to the *Amphisbænians*.

In October of 1908, before the appearance of Broili's paper just cited, Williston (69) described the skull of *Lysorophus* and objected strongly to Broili's reference of the genus to the *Rhyncocephalia* and considers it as an amphibian. This conclusion was reached independently of Case. Williston proposes the family name *Lysorophidæ* to replace the *Paterosauridæ*, as the last is not according to the rules of nomenclature. He says: "My conviction is that the *Lysorophidæ* should be included in the *Icthyoidea*."

Moody, in a paper read before the Kansas Academy of Science and published in the "Geological Magazine" in 1909 (61), proposed the following arrangement of the *Amphibia:*

Class Amphibia.

Subclass I. *Euamphibia.*
- Order 1. *Branchiosauria.*
- Order 2. *Apoda.*
- Order 3. *Caudata.*
  - Suborder 1. *Proteida.*
  - Suborder 2. *Meantes.*
  - Suborder 3. *Mutabilia.*
- Order 4. *Salientia.*
  - Suborder 1. *Aglossa.*
  - Suborder 2. *Linguata.*
  - Suborder 3. *Costata.*

Subclass II. *Holospondyli.*
- Order 1. *Microsauria.*
- Order 2. *Aistopoda.*
- Order 3. *Diplocaulia.*

Subclass III. *Stegocephala.*
- Order 1. *Temnospondyli.*
- Order 2. *Stereospondyli.*

It is regarded as doubtful whether the proposed order *Diplocaulia* should be placed in the second or the third subclass.

In 1910 Broom (1), in the "Bulletin of the American Museum of Natural History," called attention to resemblances between the South African and North American *Reptilia* and *Amphibia.*

In the same year Case (19) published in the same journal an account of several new *Amphibia* and *Reptilia* from Texas. The new forms of *Amphibia* were:

Order *Temnospondyli.*
- Family *Aspidosauridæ* nov.
  - *A. glascocki* g. et sp. nov.
- Family *Trimerorachidæ.*
  - *Tersomius texensis* g. et sp. nov.
  - *Trimerorhachis alleni* sp. nov.

A new suborder with a single known family and species was referred to the *Reptilia*, but in this paper it is referred with query to the *Amphibia.*

Suborder *Gymnarthria* nov.
- Family *Gymnarthridæ* fam. nov.
  - *G. willoughbyi* g. et sp. nov.

A study of Broili's type material, after this paper was written, revealed the fact that the specimen was very closely related to his *Cardiocephalus*, and the two are here united in one family.

CLASSIFICATION.

Order STEGOCEPHALIA.
Suborder *Microsauria.*
Family *Diplocaulidæ.*
Diplocaulus.
Suborder *Temnospondyli.*
Rhachitomus division.
Family *Eryopidæ.*
Eryops.
Parioxys.
Anisodexis (?).
Acheloma.
Family *Trimerorhachidæ.*
Trimerorhachis.
Tersomius.
Zatrachys.
Family *Dissorhophidæ.*
Dissorhophus.
Cacops.
Alegeinosaurus.
Family *Aspidosauridæ.*
Aspidosaurus.
Family *Trematosauridæ.*
Trematosaurus.
Embolomerus division.
Family *Cricotidæ.*
Cricotus.
Cricotillus.
Incertæ sedis.
Family *Crossotelidæ.*
Crossotelos.
Family *Gymnarthridæ.*
Cardiocephalus.
Gymnarthrus.
Family ———
Pleuristion.
Order URODELA.
Family *Lysorophidæ.*
Lysorophus.

SYSTEMATIC REVISION OF THE AMPHIBIA.

AMPHIBIA.

Order STEGOCEPHALIA.

Suborder MICROSAURIA (?).

Family DIPLOCAULIDÆ Cope.

Cope, Am. Nat., vol. xv, 1881, p. 164; Proc. Am. Phil. Soc., vol. xx, 1882, p. 452.
Broili, Centrlb. f. Min. Geol. u. Pal., 1902, s. 536; Paleontographica, Bd. li, 1904, s. 26.

Original description: Cope, in his first paper, regarded the *Diplocaulidæ* as belonging in the reptilian group *Pelycosauria*, but in the second paper he corrected this and gave the following definition:

"* * * the vertebral centra are not segmented, nor are the intercentra present in any form. Under this definition it must be referred to the suborder which includes *Oestocephalus*, *Ceraterpeton*, etc., for which I have adopted Dawson's name Microsauria. The division includes genera with simple amphicœlous vertebral centra, and teeth without inflection of the dentine."

Broili's description is, translated:

"Body long, serpentiform. Centra cylindrical, amphicœlous, zygosphene and zygantrum present. Ribs hollow, two-headed. Teeth conical, smooth, and hollow. Vitrodentin and enamel united and a large pulp cavity present."

Revised description: Skull enlarged, triangular; prosquamosal, quadratojugal, parietal, supraoccipital, and tabulare taking part in the formation of a large horn. Facial region very abbreviate, not over one-fifth the length of the skull. Vertebræ complete, amphicœlous; intercentra absent; diapophysis and parapophysis separate, attached to middle of vertebra. Zygosphene and zygantrum present. Ribs two-headed; attached intravertebrally. Teeth conical, without inflected dentine, large pulp cavity present. Clavicle and interclavicle present, large, sculptured on outer surface. Coracoid small, scapula unknown. Limbs present, short and weak. Humerus with entepicondylar foramen.

Genus DIPLOCAULUS Cope.

Cope, Proc. Am. Phil. Soc., vol. xvii, 1877, p. 187; also Pal. Bull. No. 26, published Nov. 20, 1877; Proc. Am. Phil. Soc., vol. xx, 1882, p. 453; also Pal. Bull. No. 35.
Broili, Centrlb. f. Min. Geol. u. Pal., 1902, s. 536; Paleontographica, Bd. li, 1904, s. 7.
Williston, Trans. Kansas Acad. Sci., 1909, p. 122.

Type: Several vertebræ, Nos. 6513, 6514, 6515, 6516 University of Chicago. From Vermilion County, Illinois, near Danville.

Original description: In the first paper cited Cope's description is as follows:

"Vertebral centra elongate, contracted medially, and perforated by the foramen chordæ dorsalis; coossified with the neural arch, and supporting transverse processes. Two rib articulations one below the other, generally both at the extremities of the processes, but the inferior sometimes sessile. No neural spines nor diapophysis; the zygapophyses normal and well developed."

In the second paper he adds the following characters:

"Vertebræ with a more or less perfect zygosphen articulation; centra shorter in the anterior than in the median part of the column; axis and atlas solidly united by a long zygosphen, which is not roofed over by the zygantrum. Neural arch continued as a short tube into the foramen magnum. Atlas unsegmented, and, like the axis, without free hypapophysis. Cervical vertebræ not distinguished from dorsals, and with two-headed ribs.

"Orbit separated from the maxillary bone by the union of the lachrymal and malar. Either the malar, or more probably the quadratojugal, extends much posterior to the quadrate bone. It is bounded above by the squamosal, which extends anteriorly to the distinct post-frontal, thus covering over the temporal fossa. Posteriorly it extends into a long, free process, like the operculum of *Polyodon*, ossified. This horn does not appear to consist of the epiotic, as appears to be the case in *Ceraterpeton*. The quadrate bone is extended very obliquely forwards and its extremity is divided into an hour-glass-shaped condyle. In other words the condyle consists of two cones with apices continuous. The internal cone is the smaller, and its base is overlapped from before by a flat bone, probably the pterygoid. The cotyli of the mandible correspond. Mandible without angle; symphysis short.

"The teeth are of about equal size, and are rather slender and with conical apex. Their surface is not inflected at any point. The superior series is double, forming two lines between which the mandibular teeth close. This superior series stands near the external edge of the vomer, palatine, and pterygoid bones successively. I have not been able to find any larger teeth in the jaws of this genus. Some fragments, mingled with those here described, display such teeth, but I think they pertain to a species of another genus. I know nothing of the limbs of this genus."

Revised description: This is contained in the revised description of the family.

Diplocaulus salamandroides Cope.

Cope, Proc. Am. Phil. Soc., vol. XVII, 1877, p. 451.
Case, Journ. Geol., vol. VIII, 1900, p. 710.

Type: The same as the genus.

Original description: "The surface of the centrum is smooth and is without grooves. The diapophyses and parapophyses are rather elongate, and are closely approximated one above the other. The superior process issues from the centrum opposite the superior margin of the articular faces. They stand equidistant from the extremities of the centrum, and are directed obliquely backwards. The anterior zygapophyses occupy the same level. The neural spine is a compressed longitudinal ridge; it divides behind, leaving a notch between the posterior zygapophyses.

"*Measurements.*

"Diameter of the centrum:	M
Longitudinal	.0060
Vertical	.0025
Transverse	.0025
Depth of centrum and neural arch	.0060
Width of transverse processes	.0070
Expanse of posterior zygapophyses	.0050"

Revised description: Skull unknown except for a fragment of a lower jaw. Vertebræ small, resembling those of larger forms, but the lower face of the centrum round from side to side instead of flat. The species is not clearly distinguished from *limbatus* or *magnicornis*, and can not be until the skull is known. The appearance of small vertebræ of uniform size in Texas, Oklahoma, and Illinois, without intermediate sizes connecting them with the larger vertebræ, warrants holding this species as separate, provisionally.

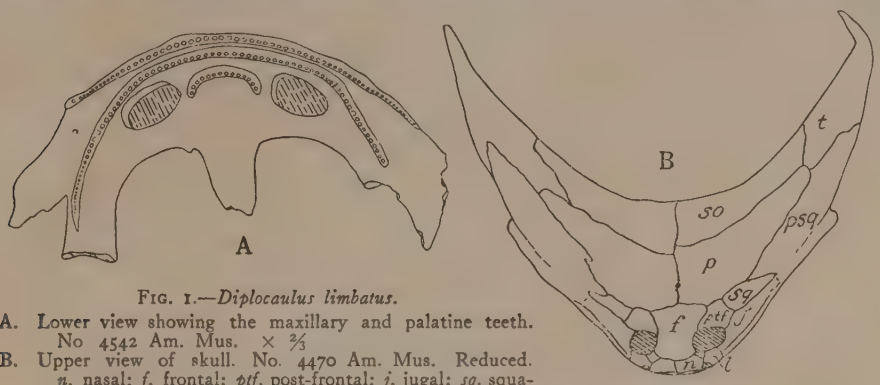


FIG. 1.—*Diplocaulus limbatus.*

A. Lower view showing the maxillary and palatine teeth. No 4542 Am. Mus. × ⅔

B. Upper view of skull. No. 4470 Am. Mus. Reduced. *n*, nasal; *f*, frontal; *ptf*, post-frontal; *j*, jugal; *sq*, squamosal; *p*, parietal; *psq*, prosquamosal; *so*, supraoccipital plate; *t*, tabulare; *l*, lachrymal.

Diplocaulus limbatus Cope.

Cope, Proc. Am. Phil. Soc., vol. xxx, 1896, p. 456.

Type: An imperfect skull. No. 4471 Am. Mus. Nat. Hist. Cope Coll. From Texas.

Original description: "The character of the species is seen in the horns. These are much less produced relatively to other regions than in the *D. magnicornis*, and the postquadrate (quadratojugal) element is more distinct and terminates in a separate apex below the principal horn. This tract, which is fused with the principal bone in the *D. magnicornis*, is separated from it by a groove in the *D. limbatus*, and the large fossa which it incloses with the inferior side of the principal horn looks inward at an angle of 45°, while it looks downward in the *D. magnicornis*. The terminal angle of the post-quadrate (quadratojugal) body forms a prominent compressed offset, rather than a free apex. In one specimen of large size it is inferolateral; in type, entirely inferior. The principal horn is shorter and narrower than in the *D. magnicornis*, and less divaricate.

"As the mandibular rami are in place and their extremities are entire, the length of the muzzle can be inferred. It is relatively longer and less broadly rounded than in the *D. magnicornis*. The surfaces of the skull are sculptured in a honeycomb pattern, as in the type species.

"*Measurements.*

	mm
"Length of the skull on median line	92
Length of the skull to extremity of horn	220
Width of skull at posterior border	160
Width of base of horn	51
Length from angle of mandible to end of horn	115
Length from angle of mandible to postquadrate process	65
Length of mandibular ramus	82
Interorbital width (approximate)	20"

Revised description:

1. Horns terminating in a point and curved inward at end. The posterior edge of skull more sharply concave.
2. Anterior edge of frontal bone but little anterior to orbits.
3. Vomerine teeth arranged in a segment of a broad curve.
4. Anterior end of skull a segment of a broad curve.
5. Sculpture of facial region distinctly radial from a point between orbits and nares.
6. Orbits larger.

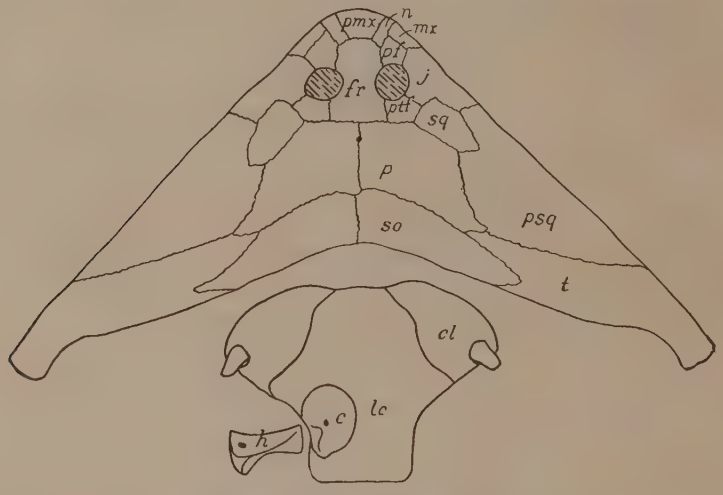


FIG. 2.—*Diplocaulus magnicornis.*

Upper view of skull. After Williston. No. 652 Univ. of Chicago. Reduced. *pmx*, premaxillary; *n*, nasal; *mx*, premaxillary; *pf*, prefrontal; *fr*, frontal; *ptf*, postfrontal; *j*, jugal; *sq*, squamosal; *p*, parietal; *so*, supraoccipital plate; *psq*, prosquamosal; *t*, tabulare; *cl*, clavicle; *lc*, interclavicle· *c*, coracoid; *h*, humerus.

Diplocaulus magnicornis Cope.

Cope, Proc. Am. Phil. Soc., vol. xx, 1882, p. 453. Also Pal. Bull. 35; Proc. Am. Phil. Soc., vol. xxxiv, 1896, p. 455.
Broili, Paleontographica, Bd. li, 1904, s. 8.

Type: A skull and vertebræ. No. 4472 Am. Mus. Nat. Hist. Cope Coll. From Texas.

Original description, from the first paper by Cope:

"The skull is very peculiar in the great extent of the parts posterior to the orbits as compared with the portion anterior to them. The posterior border not being complete, the proportions can not be exactly given, but the part anterior to the orbits is two-thirds the length of the part extending from their posterior border to near the base of the lateral horn, and one-fifth the distance from the orbit to the extremity of the horn. The part of the border of the orbit preserved indicates that the latter is of fair size. It is separated from the maxillary border by at least its own diameter. The external nares are peculiarly situated. They are nearer the orbit than the end of the muzzle, and are close to the maxillary border, being separated from the mouth by a narrow strip of bone only. They are round, open nearly laterally, and are removed from the edge of the orbits by the diameter of the latter.

"The malar or quadratojugal bone is protuberant at the canthus oris and projects laterally beyond the mandible at its posterior part. It also projects beyond the extremity of the quadrate bone. This border is continued as that of the external base of the horn, but the portion which belongs to this element is soon distinguished from the superior element (squamosal) which composes the horn, by a groove. This groove is decurved and bounds the apex of the element, which is a decurved, low tuberosity. The horn is produced backwards in a horizontal plane, forming a long, flat triangle which contracts gradually with straight sides. The apex is narrowed, obtuse, and a little incurved. Near and at the extremity the horn is flat above and convex below.

"The mandibular quadrate cotylus consists of two fossæ, which together form an approximate figure ∞, of which the internal fossa is the smaller, and opens internally. The external one is nearly transverse. The superior border of the ramus posteriorly is straight. The greater part of the superior aspect is occupied by a huge fossa which opens upwards.

"It is uncertain whether the horns meet at an entering angle on the middle line posteriorly or not, but the width of the base of the horn indicates that such is the case. The extremity of the muzzle is depressed and is broadly rounded.

"The external surface of the skull is sculptured in the form of fossæ so distributed that the narrow ridges separating them do not form straight lines, except in a few places on the superior face of the horn. This sculpture is strongly impressed and is of medium coarseness. It extends on the inferior face of the quadratojugal (?) posterior to the quadrate, and on the inferior side of the horn at the edges. It is most extended below from the interior edge, and for the terminal inch of the horn is as well marked as on the superior face. Elsewhere the sculpture of the inferior side passes into punctæ before disappearing. A groove marks the superior boundary of the maxillary bone, which divides when it reaches the superior surface. One branch descends behind the nostril, the other passes transversely across the lachrymal bone and shallows out before reaching the middle line of the muzzle. The mandible is even rougher than the superior surfaces, and has a longitudinal groove below the dental line to near the symphysis, where it runs out on the alveolar edge. The internal and external sides of the mandible posteriorly are smooth. On the malar and other facial bones there are four fossæ in 9 or 10 mm.

"The atlas is peculiarly flattened above, the neural arch being a tube, without neural spine. Its anterior tubular prolongation is not long and is deeply notched below. The condyloid fossæ are widely spread transversely and nearly flat, except that their surface is carried forwards on the neural tube. They are well separated below. There is a strong hypapophysial keel, which diminishes and runs out anteriorly. There are prezygapophysial facets, but the postzygapophyses exist. Their superior edge is, however, carried posteriorly to form the sides of the huge embracing zygantrum. These side processes, which I will call zygantropophyses, extend as far posteriorly as above the posterior end of the centrum of the axis, embracing almost the whole of the neural arch. There is another short median superior process, which notches the extremity of the zygosphen. The side of the atlas between the postzygapophysis and the condyloid facet is wrinkled, and the inferior face finely punctate.

"In the axis, the hypophysis is a large ridge with a horizontal truncate edge. The costal heads of the diapophysis are not split to the base of the latter and the superior is the more robust (extremities broken off). Centrum concave posteriorly, and on each side of hypopophysis with reticulate surface. A short zygantropophysis; zygantrum not large. Exposed summit of zygosphen (nearly equal neural arch) without neural spine. In both the axis and other cervical vertebræ, the superior diapophysis is connected with the zygapophyses fore and aft, in accord with the shortness of the centra. In the more posterior vertebræ they become separated on account of the increasing length of the centrum.

"The third vertebra is like the axis, except in having a keel-shaped neural spine, and a short obtuse zygosphen continued from its base anteriorly. With increasing length of centrum the diapophysis becomes longer, the hypophysial ridge becomes wider, and coextensive with the inferior face of the centrum. It is separated by an angle from the sides in the longer vertebræ; in those of intermediate length the inferior face is convex. All of them retain the delicate lines and punctæ of the inferior surface. The neural spine on the more elongate vertebræ is a rather elevated keel with horizontal superior edge. Its posterior extremity forms a wedge-like zygosphen. The zygantrum is a deep V-shaped cavity, opening posteriorly and not roofed over at any point, unless for a small part of its fundus. The zygapophyses are well spread and have horizontal faces. Each of the columns of the diapophysis sends a ridge forwards, which inclose a groove between them.

"*Measurements of vertebræ.*

	M		M
"Length of atlas below	0.015	Length of centrum of another (No. IV)	.022
Length of atlas at zygantropophyses	.029	Expanse of postzygapophyses of do.	.018
Expanse of atlas at condyloid facets	.034	Length of centrum of No. V	.022
Expanse of centrum atlas behind	.0145	Diameters centrum V anteriorly:	
Depth of atlas at middle	.019	Vertical	.013
Length of axis below	.015	Transverse	.012
Length of axis at zygantropophyses	.016	Expanse prezygapophyses	.021
Width of zygosphen above	.011	Elevation of neural spine from centrum	.011
Expanse of postzygapophyses	.024	Diameters centrum No. VI:	
Width of centrum posteriorly	.012	Anteroposterior	.023
Depth of centrum posteriorly		Vertical	.011
Length of centrum of another (No. III)	.018	Transverse	.013

"The vertebræ of this species are very much larger than those of the *D. salamandroides*, and the diapophyses do not originate so low down on the centrum. Otherwise they are much alike. The cranium of the Illinois species is yet undetermined."

Cope adds, in his second paper cited:

"In the typical specimen the posterior border of the skull was not preserved. The present specimen shows that it was continuous from the extremity of one horn to that of the other, and regularly concave without angles, and that it overhangs the occipital condyles a little. The posterior parts of the horns consist of the tabular bones, and the anterior portion consists of the supratemporals. The inferior part of the base of the horn externally consists of the element which articulates with the quadrate, or quadratojugal. It is distinguished from the supratemporal by a horizontal

suture. A considerable part of its surface presents inferiorly. The supramastoid lies between the supratemporal and the post frontoörbital.

"The supraoccipital extends well forward on the superior face of the cranium, the median suture equaling the length of the parietal bone. They have an extraordinary transverse extent. The median suture of the parietals is rather longer, and it is separated by the small parietal foramen at a point one-third its length from the frontal suture. The posterior width of the frontal is equal to three-fifths its length, and is a little greater than the interorbital width. It extends as far anterior as posterior to the orbits. The posterior suture is trilobate. The postfrontals are suboval with the long diameter at 45° to the median line, and the anterointernal border excavated by the orbit. They do not advance on the internal border of the latter, resembling the prefrontals in this respect. The supramastoids are necessarily well produced forwards to meet the short postfrontals, advancing far anterior to the posterior border of the jugals.

"The premaxillaries are short and wide, and are widely truncate by the frontal posteriorly. The prefrontals do not extend posteriorly to the inner border of the orbit, but they join the jugal by a considerable suture. The nasals occupy their usual position and are rather small; one of them is fused with the premaxillary in the specimen. The maxillaries are small, especially in the facial part, which does not reach the orbit. The jugal is a relatively large bone and has an irregular posterior outline, where it joins the quadratojugal and the supratemporal.

"The great expansion of the roof bones posterior to the quadrate is associated with a considerable expansion of the pterygoids in the same region. The palatopterygoid arch has the relations prevalent in the Stegocephalia, but (what is novel so far), its anterior and chiefly palatine portion carries a single series of teeth on the external and anterior border, which is concentric with the premaxillo-maxillary series, as in *Cryptobranchus*. Posterior to this is a pair of straight series of teeth, probably on the vomers, which form an anteriorly directed right angle at the middle line. They do not extend so far posteriorly as do the maxillary teeth, and the latter do not extend so far posteriorly as the pterygopalatines which terminate at a straight line drawn through the posterior borders of the orbits. The posterior nostrils are situated between the two series of palatal teeth. The external nostrils open forwards and outwards. Maxillary and premaxillary teeth twenty-three on each side. Palatines, twenty-four; vomerines, ten.

"The composition of the huge horns is thus the result of the fusion of the three posterolateral roof elements into one, thus obliterating the notch which separates the tabular from the quadratojugal bones in most other Stegocephalia."

Revised description:

1. Horns terminating more bluntly or with spatulate ends. Not curved in at ends. The posterior edge of the skull with a wide concavity.
2. Anterior edge of frontal nearly midway between orbits and nares.
3. Vomerine teeth arranged as a wide V with the apex forward.
4. Anterior edge of skull sharper.
5. Sculpture of facial region not distinctly radial.
6. Orbits smaller.

Diplocaulus copei Broili.

Broili, Paleontographica, vol. LI, 1904, p. 21.

Type: This species was founded on a series of imperfect specimens, of which there are three (Nos. 44, 45, and 47, XV, 1901), with vertebræ attached, on a single plate. They are all from Texas, north of Seymour, in Wilbarger County, and are preserved in the Museum of the Alte Akademie, Munich.

Original description (abstracted from Broili): The skulls have all suffered from pressure, so that it is impossible to give a complete description of any one; the account furnished by Broili is taken from all. The outline of the skull is crescentic and the posterior prolongations are turned somewhat towards each other, so that the posterior line of the skull is sharply concave. The position of the orbits and nares and the character of the sculpture are as in *D. magnicornis*. The sutures do not show even in a specimen which has lost the rough outer layer of the bone. The under surface of the skull can not be described in detail, because it is obscured by the pressure to which the specimens have been subjected, but it is, in all essentials, like that of *D. magnicornis*. Only the slightly concave occipitalia lateralia, the posterior ends of the pterygoids, and the parasphenoid can be made out, and these are as in *D. magnicornis*. The lower jaw reaches a length equal to one-third of that of the skull.

Measurements of four skulls are given as follows in centimeters:

	I.	II.	III.	IV.
Total length from tip of horn to middle of premaxillary region	19.5	18.8	16.2	10.1
Length of skull in middle line	9.8	9.6	9.3	6.6
Space between tips of horns	20.4	18.4	15.5	....
Distance from tip of a horn to middle of supraoccipital region	12.2	12.1	9.0	5.1
Distance of orbits from posterior border of skull	....	6.9	6.5	3.6
Interorbital space	....	1.8	1.4	....
Width of orbits	....	1.1	1.1	....
Width of skull across orbits	....	10.2	9.2	6.5
Breadth of skull near posterior border of palatal vacuities	14.1	14.2	12.5	9.0
Breadth of skull across occipital condyles	16.2	....	....	....

The vertebræ, ribs, and fragments of the clavicles and interclavicle show no great difference from *D. magnicornis*.

Broili makes the final statement that this species differs from *D. magnicornis* in the more compressed and smaller body and in the curvature of the horns which bend in towards each other, while those of *D. magnicornis* extend more directly outwards.

Revised description: It is impossible to distinguish this species from *D. limbatus* except by the smaller size, which can not be trustworthy. Of two figures given by Broili (5), plate III, fig. 1 has the characters of *D. magnicornis* and fig. 2 the characters of *D. limbatus*. The species is indeterminate.

Diplocaulus (?) pusillus Broili.

Broili, Paleontographica, Bd. LI, 1094, p. 24.
Williston, Trans. Kans. Acad. Sc., 1909, p. 122.

Type: A small skull with a few attached vertebræ. No. 65, XV, 1901. Museum of the Alte Akademie, Munich. From Wilbarger County, Texas.

Original description: Broili believed at first that this was the skull of a young *Diplocaulus*, but the completely ossified skull and the presence of

well-defined sutures led him to the belief that it was the adult of another species. Skull very flat and small. Length on the middle line of one, 2.6 cm.; of another 1.9 cm. Sculpture as in the larger forms but finer, so that the pits of the larger skull are here small points. Centers of ossification can be made out in the individual bones, but there are no traces of slime canals or of a sclerotic ring in the eye. Orbits and nares in relatively the same position as in *Diplocaulus*. Supraoccipital relatively large and broad, meeting the epiotic (tabulare) laterally. Large parietal not clearly separated from the frontal. Frontals apparently united in a single bone. Quadratojugal a slender element forming the side of the posterior part of the skull, which is continued backward into well-developed horns. Space between the quadratojugal and the parietal filled by a single element which, in all probability, must be considered as the supratemporal. The sutures of the anterior part of the skull can not be made out. The lower jaw with an inconspicuous sculpture, longer than in other species of the genus, reaching to a length equal to one-half the length of the skull. The slender teeth conical, smooth, and of equal size. Four vertebræ, beginning with the atlas, are visible from the upper side; they are similar to those of *Diplocaulus* except that the atlas is more slender. Interclavicle elongate rhomboidal, with the sculpture radiating from the center of ossification, which lies about in the middle of the plate. The clavicle has a leaf-like outline with the center of ossification near the outer border.

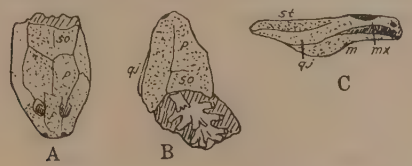


FIG. 3.—*Diplocaulus (?) pusillus*. × ⅔ after Broili.
A, upper view; B, upper view of a second specimen; C, lateral view of a third specimen.
f, frontal; *p*, parietal; *so*, supraoccipital plate; *qj*, quadratojugal; *st*, prosquamosal; *m*, mandible; *mx*, maxillary.

Williston, in the paper cited, regards it as very doubtful whether this form belongs to the genus *Diplocaulus*.

Revised description: So far as our knowledge now goes, the original description seems adequate for this uncertain form. A specimen of this animal, No. 4523 Am. Mus., strongly suggests relationship to *Trimerorhachis*.

Suborder TEMNOSPONDYLI Zittel.

A. RHACHITOMUS division.

Family ERYOPIDÆ Cope.

Cope, Am. Nat., vol. xvi, 1882, p. 334. Proc. Am. Phil. Soc., vol. xx, 1882, pp. 460–461. Syllabus of Lectures, 1891, p. 29. Syllabus of Lectures, 1898, p. 46.

Original description: In the first paper Cope suggested the recognition of a new suborder, the *Rhachitomi*, which he divided into two families:

"Occipital condyle concave, undivided.....*Trimerorhachidæ*
Occipital condyle divided into two lateral condyles.....*Eryopidæ*"

Revised description of the family:

1. Small to large. Reaching from 2 to 2.5 meters in length.
2. Occipital condyles distinct.
3. Otic notch small.
4. Parasphenoid large joining a basioccipital posteriorly.
5. A single sacral rib.
6. No dermal armor on back.

7. Clavicles and interclavicles without sculpture.
8. Cleithrum present.
9. Humerus heavy, ends at right angles to each other.
10. Femur with prominent ridge on ventral surface.
11. The two halves of the neural spine united.
12. Intercentrum thick and heavy, nearly closing notochordal space.

Genus ERYOPS Cope.

Cope, *Eryops*, Proc. Am. Phil. Soc., vol. XVII, 1878, p. 188; Proc. Am. Phil. Soc., vol. XVII, 1878, p. 520; Proc. Am. Phil. Soc., vol. XIX, 1880, p. 51.
Broili, *Eryops*, Paleontographica, Bd. XLVI, 1899, s. 61.
Cope, *Epicordylus*, Proc. Am. Phil. Soc., vol. XVII, p. 515.
Rhachitomus, Proc. Am. Phil. Soc., vol. XVII, p. 526.

Type: A good skull with lower jaws and numerous vertebræ and bones of the girdles. No. 4189 Am. Mus. Nat. Hist. Cope Coll. From Texas.

Original description: Of the genus *Eryops*, the original descriptions of the synonyms are given below.

"The skull is not elongate, and the quadrate bones are produced far backwards. The epiotic processes are present, but not remarkably elongate. The temporal fossa is covered by the usual roof. The orbits are round, posterior in position, and small. There is no postorbital depression or groove, and the lateral epiotic sinus is not deep. The nostrils are large and widely separated. There is no angular process of the mandible. The maxillary teeth are of different sizes, although arranged in a single row. The posterior are small and not closely placed; large teeth appear anterior to the middle. The premaxillary bone supports a number of large teeth. Those of the mandible which are visible in the specimen in its present state, those opposite the nares, are of medium size. The form of the crowns of the teeth is conic, with weak fore-and-aft cutting edges. There are no distinct fissures of the surface although these may be represented by some fine parallel lines.

"Vertebræ referred to this genus are small in proportion to the dimensions of the skull. They are not discoidal but somewhat elongate; are biconcave, and are not perforated for the notochord. The middle portion of the centrum is contracted. One articular extremity has the borders of the concave center convex. Zygapophyses large. Ribs present, short; neural spines elongate, stout."

In the second paper Cope adds:

"A series of a few large teeth much exceeding the maxillaries in size within the latter, perhaps on the palatine bone. No row of smaller teeth within the maxillary series, or on the vomer, as in *Mastodonsaurus* and *Capitosaurus*. The choanæ are large, and extend well forwards."

In the third paper he gave an extended description:

"The largest element of the vertebra is the intercentrum. This, which occupies the entire inferior surface of the vertebra, is a segment, representing the sixth part of a sphere, with a slight central vacuity. The element representative of the centrum is wedged in between the superior external angles of adjacent intercentra, as in *Trimerorhachis*. These, as well as the intercentra, differ from those of that genus in their greater degree of ossification, which is so far complete as to greatly contract the *canalis chordæ dorsalis*. The central elements of opposite sides do not unite on the middle line below, although in contact. The neurapophysis is produced downwards

and outwards, terminating in the simple diapophysis, with rib articulation. The inferior articular faces of the arch are two on each side, one for the central element in front, and the other for the one behind it. The whole is surmounted by a continuous neural spine, which is expanded at the summit in the known species. The vertebræ do not differ much in different parts of the column. The cervicals are not distinguished in any way from the dorsals, but their anterior intercentra have more extensive costal surfaces, which give the inferior posterior border lateral angles. The diapophyses of the second and third cervicals are of reduced size. The neural spine of the axis is a little less elevated, and is longer anteroposteriorly than that of the third and succeeding cervicals. I do not possess an entire atlas free from matrix. Attached to the axis of this specimen are two elements which connected it with the skull, as they are separated from it only by closely fitting fractures. The elements are lateral, and each presents a semi-spherical, articular face in front, and a long process with acute apex at right angles to it, posteriorly. These processes lie, one on each side of the neural spine of the axis, above the position which would be occupied by its prezygapophysis; they represent the distinct halves of the arch of the atlas. At the superior base of each process near the edge of the articulation is a button-like tubercle, which represents a prezygapophysis; the inferior articular faces correspond with those of the occipital condyles in form but not in position, which is inverted. The inferior elements of the atlas are lost.

"The intercentra are rather longer and more elevated in the sacral region. One only can be properly said to belong to the sacrum, and this is closely united with the one that follows it by a rough surface of contact. In old animals it may become coossified. What the relations to the intercentrum immediately preceding may be, I am unable to state, owing to the condition of the specimen. A pair of caudal vertebræ are peculiar. Their intercentra are in contact throughout, excluding the pleurocentra. The latter rest above the intercentra and between the inferior parts of adjacent neural arches. Each intercentrum supports a coossified chevron bone, and these, in the two vertebræ in question, become coossified with each other, forming a robust rod directed backwards, whose double base is perforated by the hæmal canal. This peculiar structure probably belongs near the extremity of the caudal series, as the anterior caudals observed in other specimens are much like the dorsals.

"The costal articulations are everywhere undivided, and have an obliquely vertical extension. The articular surface extends to the intercentrum in the *E. megacephalus*, forming a short superficial depression which enters from the supero-posterior border. The costal surfaces of the diapophyses become more robust anteriorly and are more narrowed, especially at the middle and inferior portions, posteriorly. The diapophysis of the sacral vertebra is very robust, and presents a large tubercular face downwards and a little backwards. The external side of the intercentrum about its superior angle is also covered by a large capitular facet, and the two facets support a sacral rib. This element is much more robust anteriorly than the true ribs, and its capitular and tubercular facets are distinct from each other, although they are separated by a slight interruption. The body of the rib is plate-like and is directed downwards and backwards, its union with the ilium being squamosal. The costal elements posterior to the sacrum diminish rapidly in size. From the size of the vertebræ in *E. megacephalus*, the tail is probably of medium length only.

"The coracoid is but little incurved; its internal border is convex, and is roughened as though for cartilaginous attachment. Its superior portion forms a convex continuum with the scapula. The direct line or external face of the scapula extends in a nearly plane surface to the glenoid cavity, embracing a perforating foramen above the latter, precisely as in the *Pelycosauria*. Its surface is continuous anteriorly with a wide expansion forwards, whose fine, inner border is continuous with that of the coracoid. This plate doubtless includes a third element, but its borders are not preserved, on account of the obliteration of the sutures. It is probably epicoracoid, as in the *Pelycosauria*. In its form it is less produced than in the known scapular arches of the latter.

"The coossified pelvic elements resemble, in their compression below, the corresponding parts in the *Anura*. The ilia are, however, shorter and worn as in the *Urodela*. They are flat and stand at right angles to the line of the ischiopubic symphysis. There is an open concavity of their inferior posterior free border, and a facet-bearing elevation on the inferior border, or that entering into the formation of the acetabulum. The latter is large and half as long again as deep. The anterior and posterior borders of the pelvis descend regularly to the inferior edge, forming with it a triangle. The ischiadic or posterior border is but little thickened; the anterior or pubic is flat in front and presents a reverted edge outwards. This expands prominently where it is joined by a ridge which bounds the acetabulum below; it there contracts to an inferior apex. Beneath the anterior point of the acetabulum it is pierced by the usual foramen, which issues on the inner edge of the anterior face, just above the symphysis.

"The humeral bones of this genus I probably possess, but I have several forms between which I am not able to decide. They are in general like those of the *Pelycosauria*, but differ from them in not having an inclosed supracondylar arterial foramen, but only the buttresses of its inclosing arch. Two such forms I have already described, and a third has been obtained from the French Permian by Professor Gaudry. One quite similar to the latter I have since obtained from Texas. Not having been able at first to determine the proper reference of these humeri, I suggested to Professor Gaudry that his humerus belongs to one of the *Pelycosauria*, and he accordingly described it as *Euchirosaurus rochei*. I now think that there is greater reason for believing that it belongs to a species of the same group as *Eryops* and *Actinodon*.*

"In all these humeri the extremities are expanded in different planes, and the shaft contracted. The articular surface of the proximal extremity is band-like and passes obliquely from one side to the other, as in the *Pelycosauria*. The condyles are large, consisting of a globular portion and a depressed trochlea without ridges at one side of it.

"The femora are very different from the humeri, but in much the same way as in the corresponding bones of existing *Batrachia*. There are no condyles at either extremity, but outlines of such, inclosing roughened surfaces. These look as though the bases of attachment of cartilaginous caps or epiphyses. The proximal extremity is convex, and is extended in one direction. One border, the anterior, is regularly gently convex; the opposite arc is strongly convex near one end only. The articular face is in two planes, one larger than the other. The trochanteric fossa is at first shallow, and

*Thevinin has recently shown (66) that *Euchirosaurus* must be regarded as a synonym of *Actinodon*.

occupies the entire width of the bone; it narrows with the shaft downwards and the borders rise, one more than the other. The two join in a strong protuberance, which looks directly backwards, and may be called for the present the third trochanter. The shaft is keeled below and in continuation of the trochanter, to where it expands for the distal articular extremity. The latter looks partly downwards, and is divided by a deep groove above into two parts representing the usual condyles. One of these is comparatively depressed, while the other has a massive superior crest, which makes its long axis vertical instead of horizontal, as is that of the other condyle."

Below are given the original descriptions of *Epicordylus* and *Rhachitomus:*

Char. Gen.: "*Epicordylus* is known from a large part of the vertebral column, including all the regions excepting the cervical, so far as at present appears. In general the vertebræ resemble those of *Clepsydrops*, having well-developed intercentra. The diapophyses are at the base of the neural arch, and are prominent, and with large undivided articular extremity; they are not present on the caudal vertebræ. The neural spines are compressed below and enlarged transversely above, so as to be claviform. They are not elongated over the lumbar or sacral regions, but are similar to those of the dorsal vertebræ at those points. The *ossa ilii* resemble those of *Clepsydrops*. The zygapophyses are as usual oblique upwards and outwards, and the centra are not shortened."

Char. Specif.: "The centra are a little compressed, and higher than wide. In the anterior caudal region they are a good deal more compressed. The intercentra in a part of the dorsal series are larger than in any known species of *Clepsydrops*. The neural spines are bilobed at the apex on the sacral region, and become shortly bifurcate on the caudal series.

"*Measurements.*

	M
"Length of a series of seventeen dorsal vertebræ	0.610
Length of an anterior neural spine	.050
Length of posterior	.070
Length of tubercular costal face of anterior dorsal	.020
Length of tubercular costal face on seventh vertebra of the series from the last	.035
Length of five caudal vertebræ of probably the same animal	.180
Elevation of fourth caudal neural spine	.057
Width of neural spine at summit	.035
Length of ilium	.120

"This species appears to have been about the size of the Mississippi alligator. Unfortunately the cranium is unknown, but probably some of the jaws and teeth in my possession belong to it."

Rhachitomus:

"Each vertebra consists of two segments, an intercentrum and a neural arch. The true centrum is wanting in the specimens at my disposal, and the intercentrum supports portions of two adjacent neural arches. With these it shares the intervertebral articular face usually borne by the centrum. Each articular face is thus divided into three portions, one-third belonging to each neurapophysis and one-third to the intercentrum. Between these the course of the chorda dorsalis is unobstructed. Neural spine present coossified. Diapophysis large, with a subvertical tubercular costal face. Zygapophyses well developed.

"The absence of centrum and presence of neural spine and articular faces of the neuropophyses, with the well-developed diapophyses, distinguish this genus from *Trimerorhachis*. The large intercentra and articular faces of the neural arch distinguish it from *Archegosaurus*."

Char. Specif.: "The *Rhachitomous valens* is a much larger species than the *Trimerorhachis insignis*, equaling or exceeding the *Empedocles alatus*. The intercentra are very robust; the posterior face is nearly straight, while the inferior border of the anterior face curves backward to meet the former at an angle. The inferior face is convex transversely and slightly concave anteroposteriorly. The tubercular rib facets are oval, and are narrowed downwards and forwards. The side of the neurapophysis describes a curve which rises a little to the superior part of the extremity of the diapophysis. The zygapophysial surfaces are as wide as long, and a little oblique. The neural spine is not very elevated and is very robust; its section is a longitudinal oval. The summit is truncated and thickened laterally.

"*Measurements.*

"Diameter of intercentrum:	M
Transverse	0.035
Antero-posterior	.023
Expanse of the diapophyses	.073
Length of tubercular surface of do	.022
Elevation of neural arch	.071
Elevation of neural spine	.040
Antero-posterior diameter of summit of do	.044"

The mistakes in these descriptions and the identity of the specimens with *Eryops megacephalus* are now sufficiently obvious, but they are reprinted to show the development of our ideas concerning these forms.

Revised description:

1. Large, 2 to 2.5 meters.
2. Otic notch present.
3. Orbits proportionately small, a little posterior to the middle of the skull.
4. Nares some distance from the anterior and lateral edges.
5. Angle of lower jaw not produced behind the quadrate.
6. Lower jaw rather wide, vertically.
7. Skull covered with a coarse sculpture, especially strong on posterior portion.
8. Teeth irregular in size. Large tusks, in pairs, on prevomers, palatines, and maxillaries.
9. Dentine simply but strongly infolded.
10. Fine teeth on prevomers, pterygoids, and parasphenoid.
11. Ribs expanded with angular extension of posterior edge.
12. A single sacral rib.
13. Pelvis narrow, with a long and narrow symphysis.
14. Spines of dorsal vertebræ rugose at apex.
15. Spines of caudal vertebræ with bifurcate apices.
16. Humerus short, with powerful processes; proximal and distal extremities at right angles.
17. Femur with a narrow and high ridge on posterior face.
18. Feet short and wide.

Eryops megacephalus Cope.

Cope, Proc. Am. Phil. Soc., vol. XVII, 1877, p. 188; Am. Nat., vol. XVIII, p. 29.
Broili, Paleontographica, Bd. XLVI, 1899, s. 61.

Type: The same as the genus.

Original description: "The cranium has a subtriangular outline, with the sides a little longer than the base, and the apex (muzzle) very obtuse. The profile is elevated behind, and the sides slope steeply to the mandible; the slope of the muzzle is rather steep, but less so than that of the cheeks. The extremity of the snout is broadly rounded and depressed and overhangs the mandible. The supraoccipital outline is concave, and the epiotic angles only moderately prominent. The quadrate bones extend far posteriorly, and are horizontal above at their distal extremities. The orbits are nearly round, although somewhat wider than long, and they are directed equally outwards and upwards. The inner margin is slightly flared upwards, and it terminates anteriorly and posteriorly in a slight tuberosity, at the junction with the canthus rostralis and temporal ridge respectively.

"The orbit occupies the anterior portion of the posterior third of the length of the skull, including the epiotic angles; and its long diameter is one-seventh that of the skull from the epiotics to the muzzle inclusive. The same diameter is about half the interorbital width. The parietal region is plane, the frontal gently concave, and the muzzle depressed convex in cross-section. The face in front of the orbit is concave below the canthus rostralis. The nostrils are not large, and are subround. They are widely separated, being nearer the maxillary border at its junction with that of the premaxillary than to the median line. The mandible is shallow and not very stout. Its inferior border rises from below a point a little in front of the fundus of the epiotic sinus to the angle, which is at the quadrate articulation. Symphysis short.

"The sculpture of the anterior portion of the muzzle is coarsely punctate; on the posterior portions of the upper and lower jaws it is ridged and pitted. Most of the upper surface of the skull is still covered with a thin layer of the matrix so that the sculpture and the character of the lyra, if any there be, remain unknown.

"The teeth, as has been observed, are not visibly grooved, but the characteristic feature of the group may be represented by numerous delicate crack-like lines, which one sees on the basal portions. These, however, resemble the result of weathering. The sections of all the teeth would be round, but for the cutting edges, which are not very prominent. In addition, the premaxillary teeth are coarsely fluted on the median half of their length. The fluting is not visible on an antero-lateral mandibular tooth, nor on a posterior maxillary tooth. The microscopic structure of the teeth is not yet investigated.

"The bodies of the vertebræ have concave sides and a sub-round section. The neural spines terminate in an obtuse enlargement. Many of the characters of the vertebral column are yet concealed in the matrix. The distal portions of the ribs are straight, cylindric, and become stouter at the extremity.

"*Measurements.*

	M		M
"Length of the cranium from the extremity of the os quadratum..	0.433	Length of premaxillary tooth	0.025
Length of the cranium on middle line	.335	Diameter of premaxillary tooth ...	.007
Length from end of muzzle to nostril	.073	Length of posterior maxillary tooth	.010
Width of cranium between quadrates	.306	Diameter of median maxillary tooth	.007
Width of cranium between epiotics..	.118	Length of a dorsal centrum	.024
Width of cranium between orbits...	.086	Vertical diameter of do	.025
Width of cranium at orbits.....	.294	Vertical diameter of do	.025
Width of cranium between nares....	.085	Elevation of neural spine of do	.050
Diameters of orbits:		Length of rib on curve	.080"
Antero-posterior.....	.048		
Transverse.....	.057		

Revised description: This is contained in the revised description of the genus.

Eryops reticulatus Cope.

Am. Nat., vol. xv, 1881, p. 1020.

Type: Several small intercentra. No. 4786 Am. Mus. Nat. Hist. Cope Coll. From New Mexico.

Original description: "The most prominent peculiarity of this species is seen in the neural spines, which are not expanded at the summit, as in *E. megacephalus*, but have rather contracted apices. Another character is the sharply reticulate sculpture of the maxillary bones. The species is much smaller than the *E. megacephalus*, or even than the *T. insignis*, and the extent of the ossification of the vertebral elements is intermediate between the two species. The inferior surfaces of the intercentra are smooth, and the diapophyses are compressed. The occipital condyles are depressed and not very well distinguished inferiorly. The humeri have expanded extremities with enlarged epicondyles, well-developed condyles, and no epitrochlear foramen. Width of occipital condyles, m. 016; elevation of dorsal vertebra, .024; width of intercentrum, .011; length of intercentrum (below), .007; five maxillary teeth in .015."

Revised description: It is impossible to identify the parts used by Cope in this description. This species and *Zatrachys apicalis* were described by Cope from a mass of clay which contained the mixed remains of several animals. The intercentra seem the only parts which can be identified as having been in Cope's hands when the description was written. The species is very doubtfully to be referred to *Eryops*, both from its morphological character and its geographical position (see fig. 40, page 109).

Eryops (?) platypus Cope.

Icthycanthus platypus, Proc. Am. Phil. Soc., vol. xvi, 1877, p. 574.
Eryops platypus, Trans. Am. Phil. Soc., vol. xvi, 1888, p. 289.

Type: A portion of a skeleton including a front foot. From Linton, Ohio.

This species was originally described as a distinct type of amphibian, but later referred to the genus *Eryops* because of its apparent rhachitomus vertebræ and the structure of the foot. It may be a member of Cope's group of the *Rhachitomi*, but the foot in no wise resembles that of *Eryops*. It can not be considered a member of that genus.

Eryops latus Case.

Journ. Geol., vol. XI, 1903, p. 394.

Type: A scapula with the cleithrum attached. No. 182 University of Chicago. From Texas.

Original description: "The scapula differs from that of *Eryops megacephalus* in the relatively greater breadth of the coracoidal region and the straightness of the anterointernal edge. The cleithrum is a queerly shaped bone; the posterior end is thin and greatly expanded so that it overlaps the upper portion of the distal end of the scapula and is closely applied to it as a thin scale; it is convex outwardly. The anterior two-thirds of the bone is rounded and rod-like. It lies close to the upper edge of the scapula, but is to be described as applied to it rather than being articulated with it, for where the bone is broken away the edge of the scapula is smooth and complete. The edges of the rod-like portion of the cleithrum were evidently extended as narrow and very thin wings. The anterior edge is sharp and marked with rugosities where it joined the clavicle, as is indicated in Cope's figure. Broken fragments of the clavicle were found with the scapula and show that the anterior face of the proximal portion was marked with very deep and rugose striations and ridges. The evidence of the cleithrum afforded by this specimen makes our knowledge of the shoulder-girdle of *Eryops* complete.

"*Measurements of E. latus.*

	M
"Breadth across epicoracoid region	0.182
Breadth opposite center of face for humerus	.079
Width of scapula at middle	.073
Greatest length of scapula	.371
Greatest length of cleithrum	.237"

Revised description: This species is based on the character of the anterior edge of the scapula. In *Eryops megacephalus* this edge is broadly convex, but in *E. latus* the edge is flat or concave and it is longer, compared to the length of the scapula, than in *E. megacephalus*. The species is probably a good one, but needs confirmation.

Genus PARIOXYS Cope.

Proc. Am. Phil. Soc., vol. XVII, 1878, p. 521.

Type: Two small skulls. Nos. 4309, 4310 Am. Mus. Nat. Hist. Cope Coll. From Texas.

Original description: "Suborder *Labyrinthodontia*. Head of medium proportions, with orbits near the middle of the length, and lateral external nares. Epiotic bones prominent, bounding a deep, auditory notch. Mandibular angle projecting beyond the glenoid cavity. Maxillary and premaxillary teeth not large, conic, subequal; within them a series of rather numerous teeth, of near the same size, probably rising from the palatine bone. No lyra discoverable.

"This genus resembles *Rhinosaurus* and *Eryops*, but belongs to the group with prolonged mandibular angle. Among these it differs from *Mastodonsaurus* and its immediate allies in the deep auditory notch and prominent epiotic bones. From *Labyrinthodon* and *Anthracosaurus*, the uniform sizes of its teeth distinguish it; while there is no indication of the facial fontanelle of *Dasyceps*, which is otherwise much like *Parioxys*."

Parioxys ferricolus Cope.

Proc. Am. Phil. Soc., vol. XVII, 1878, p. 521.

Type: The same as the genus.

Original description: "This salamander is represented by two crania of similar size, to one of which a few vertebræ are attached. I have not yet removed the matrix inclosing the latter, as it is a task requiring much time. The general form of the skull is a triangle with rounded sides and narrowed and obtuse apex. The parietal region is rather elevated and wide, and is bounded by a low, angular ridge, which extends anteriorly from the epiotic angle, diminishing in prominence to the orbit. The external border of the epiotic next the auditory notch is acute, and the posterior angle is decurved, as though it formed the rim of a large *membranum tympani*. Between the epiotic cornua the supraoccipital border is concave. The middle of the parietal region is concave.

"The orbits are large and have prominent rims, which separate a concave, interorbital region, which is less than half as wide as the longest (antero-posterior) diameter of the orbit. The rim is most prominent at the front of the orbit, anterior to which the side of the muzzle is somewhat swollen. There is no canthus rostralis; in its stead there is a concavity behind the nares, with an intervening swelling just behind the latter. These are equally lateral and superior in their presentation. The middle of the muzzle is slightly concave, with a low, median longitudinal ridge. If there be any sculpture of the surface of the cranial and mandibular bones, it must be slight; where the thin layer of the fine-grained matrix which invests it has been removed, it is smooth.

"The crowns of the teeth are rather slender; one from the posterior part of the premaxillary bone does not display any cutting edges nor facets. The grooves of inflection are strong and extend well towards the apex, but they are not numerous.

"*Measurements.*

	M
"Length of skull from the muzzle to epiotic angle	0.100
Length of skull from the muzzle to supraoccipital	.090
Length of skull from the muzzle to front of orbits	.045
Length of skull from the muzzle to nares (axial)	.012
Width of skull at extremities of quadrates	.083
Width of skull between epiotic angles	.035
Width of skull between orbits	.015
Width of skull at front of orbits	.066
Width of skull between nares	.015
Long diameter of orbit	.025"

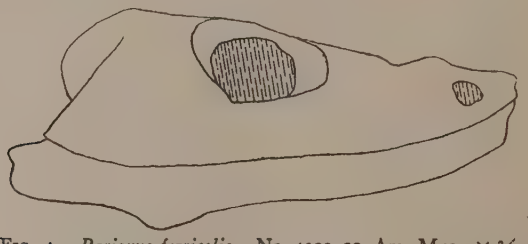


FIG. 4.—*Parioxys ferricolis*. No. 4309–10 Am. Mus. × ¾.
Lateral view of skull.

Revised description of the genus and species: This animal is represented by the skull alone and was considered by Cope as a young *Eryops*, but there

seem to be differences too great to permit this. The skull is small and the creature could not have been over half a meter long at the greatest. The orbits are proportionately large. The nares more nearly terminal than in *Eryops* and nearer to the lateral edge. The angle of the jaw is continued beyond the quadrate. The lower jaw is much narrower, vertically, than in *Eryops*.

Genus ANISODEXIS Cope.

Proc. Am. Phil. Soc., vol. xx, 1882, p. 459; Am. Nat., vol. xviii, 1884, p. 36.

Type: A few fragments of a skull. No. 4556 Am. Mus. Nat. Hist. Cope Coll. From Texas.

Original description: "Class Batrachia; order Rhachitomi; family Eryopidæ. Teeth on premaxillary, maxillary, and dentary bones of unequal lengths, some very large, others very small. Dentinal inflections straight, nearly reaching the pulp cavity. Cranial surfaces sculptured.

"This genus differs from all the others of the *Eryopidæ*, in the great and abrupt inequality of the teeth of the external series of the mouth, resembling in this respect some of the Saurians of this deposit, rather than the batrachia. Whether it possesses long palatine or pterygoid teeth, such as most of the latter exhibit, is not rendered clear by the specimens, but appearances indicate the presence of one near the anterior part of the maxillary. Mandibular series simple."

In the second paper the description is as follows:

"The genus differs from those previously described in the inequality of the size of the teeth of the external series. Thus in the upper jaw there is a very large one near the symphysis. The neural arch of the vertebræ resembles that of the genus *Acheloma*. The *A. imbricarius* Cope is the only known species, and is represented in the collection by fragments only. The size of the skull is nearly that of *Eryops megacephalus*. The sculpture of the superior surface of the skull is a coarse reticulation; that of the sides of the jaws is of an imbricate or shingle-like pattern. The vertebræ do not exhibit an expansion of the neural spine."

Anisodexis imbricarius Cope.

Proc. Am. Phil. Soc., vol. xx, 1882, p. 459.

Type: The same as the genus.

Original description: "Founded on numerous fragments of the skull with jaws, and a vertebral arch and spine found in connection with the remains of the *Diplocaulus magnicornis*. These pieces indicate a larger species than the latter, and are nearly equal to the *Eryops megacephalus*. The jaws are not preserved entire, but portions from different parts of the length display the dental characters.

"The sculpture of such parts of the superior surface of the skull is a coarse reticulation, coarser than in any other species known to me. Near the edges, some of the bones become smoother, and the ridges flatten into overlapping laminæ. The entire sculpture of the dentary bone is of this imbricate character, the apparent overlapping being from before backwards, and below upwards. This is totally different from what is observed in the other known species of *Eryopidæ*, *Trimerorhachidæ*, and *Diplocaulidæ*. The teeth are round in section, but become lenticular near the apex, developing low cutting edges. The basal grooves are fine, but distinct, and extend half-way

to the apex, or farther. One large and one medium-sized teeth stand on each dentary bone near the symphysis, and there are two similar ones at a point further back on the same bone. Near the anterior part of the maxillary below the (?) nostrils, is a huge tooth, with a graduated series of small teeth posterior to it, and a very small one anterior to it.

"The neural arch of a vertebra has a well-developed vertical spine. Its neurapophysis rested in an oval fossa of the centrum which probably was divided into pleurocentra. The prezygapophyses are very small and look directly upwards. The postzygapophyses are much larger and look obliquely outwards and backwards. The spine is not expanded at the summit and is granular, as though it was protected by a cartilaginous cap. Its section is anteroposteriorly lenticular, with acute edge (angle) posteriorly and a very narrow truncate edge anteriorly. The latter is bounded below just above the root of the neural arch by two little fossæ. The posterior keel is bounded below by a corresponding single fossa. The posterior acute edge of the spine is dentate and the surface on each side of it is beveled with rabbeted surfaces as though for a coarse squamosal suture. But the appearance of suture is fallacious, and is simply due to contraction of the transverse diameter of the spine. The neurapophysis is much narrower antero-posteriorly than the neural spine.

"*Measurements.*

	M
"Depth of maxillary bone at large anterior tooth	0.037
Depth of dentary at symphysis	.025
Depth of dentary near middle	.021
Width of dentary near middle	.015
Diameter of base of large maxillary tooth	.010
Diameter of small maxillary tooth	.0035
Length of small maxillary tooth	.008
Length of large mandibular tooth near symphysis	.016
Diameter of base of crown of do	.006
Elevation of neural arch	.037
Diameters neural spine, vertical	.029
Diameters neural spine, at apex:	
Anteroposterior	.019
Transverse	.012
Width neurapophysis anteroposteriorly	.010"

Revised description of the genus and species: This genus and species are known only from a few fragments of the jaws and other bones and can not be compared with the other members of the family *Eryopidæ*, in which it is provisionally placed. The sharp, rather recurved teeth and the peculiarly imbricate appearance of the surface of the bone are totally different from any other form from the Texas beds.

Genus ACHELOMA Cope.

Proc. Am. Phil. Soc., vol. xx, 1882, p. 455; Am. Nat., vol. xviii, 1884, p. 35.

Type: A skull with a good portion of the vertebral column and some of the limb bones. No. 4205 Am. Mus. Nat. Hist. Cope Coll. From Texas.

Original description: "Order Rhachitomi; family Eryopidæ, differing from *Eryops* in the absence of notch of the posterior border of the skull between the epiotic and quadrate or squamosal bones, and in the absence of condyles of the humerus.

"Mandible without angular process. Teeth of the jaws subequal, rather larger anteriorly; some large ones on the *os palatinum* at different points along the external margin. Pterygoid bone ending in a free, decurved edge anterior to the quadrate bone. Palatines and pterygoids narrow, leaving a wide palatal foramen. Vertebræ in their principal features as in *Eryops*. The humerus is unlike any of those enumerated in my synopsis of Permian humeri, but resembles the one figured by Gaudry as belonging to *Actinodon*, except that in *Acheloma* there are no condyles and there is an epicondylar foramen. This is the first time I have observed the foramen in a Batrachian, though it is universal, so far as known, in the Pelycosauria. As in *Actinodon*, there is a short process above the external epicondylar angle.

"The absence of humeral condyles in this genus is paralleled by the same feature in *Clepsydrops natalis*. It looks as though the animal were young and had not yet attained to the coossification of epiphyses. This theory may account for the condition of the humeri in the two species mentioned. It occurs equally in the *Trimerorhachis insignis*. As all these species show every other indication of maturity, and as I have never yet observed free epiphyses in any of my numerous Texan collections, I am disposed to look on this condition of the humeri as a case of permanent incompleteness, of which the Batrachia present so many instances."

In the second paper Cope's description is as follows:

"The genus is allied to *Eryops*, and differs in two principal points. One of these is absence of the lateral border of the cranial table formed by the external side of the *os intercalare* in *Eryops* and various other genera, the posterior outline of the skull being continuous. The other is the absence of the condyles of the humerus, a point in which it resembles *Trimerorhachis*. The vertical segments are more robust than in *Trimerorhachis*, and less so than in *Eryops;* and it agrees with those genera in the absence of the mandibular, angular process.

"The only known species of this genus is the *A. cumminsi* from Texas. Its structure is pretty well known. It resembles in general the *Eryops megacephalus* with its small orbits and absence of lyrate groove, but is smaller and differs in various details. The skull is triangular and measures a little more than seven inches long by five wide, and has an open honeycombed sculpture of the surface. The vertebræ and limbs are small for the size of the skull; and in the former the summits of the neural spines are not expanded."

Acheloma cumminsi Cope.

Proc. Am. Phil. Soc., vol. xx, 1882, p. 455.

Type: The same as the genus.

Original description: "This animal is represented by a greater part of a skull and vertebral column, with both humeri and scapulæ and various other bones of the limbs, includ ng phalanges. All of these remains look a good deal like *Eryops megacephalus*, and they might be supposed on hasty examination to belong to the young of that species. On a full investigation the following differences appear, besides those already mentioned in the generic diagnosis:

"The muzzle is relatively much shorter and the extremity is less depressed; the length from the supraoccipital forwards is a little less than the total width at the same point. In agreement with this, the mandibular rami,

after diverging strongly from the symphysis, are strongly incurved to the quadrate, a form not found in *E. megacephalus*. The sculpture is more sharply defined in the present species. In the vertebræ, although the intercentra have the same degree of ossification as in the *E. megacephalus*, the neural spines have not the expanded head of those of the larger species, but look as though they had lost an epiphysis, as in the case of the humeri. They are erect, with subquadrate section, and not oblique and grooved as *Trimerorhachis insignis*. The diapophyses are more elongate than in *E. megacephalus*, and their extremities frequently have a subround or suboval section, and but few have the narrow surface seen in *E. megacephalus*. The ribs are short and flat, and have the distal extremities expanded paddle-shape. Laid backwards such a rib reaches to the posterior edge of the third diapophysis posterior to the one to which it is attached.

"The form of the skull is triangular, with rounded apex or muzzle, and a slight contraction behind the nostrils. The latter are near the edge of the jaw and open equally laterally and superiorly. The orbits are of medium size and are as far from the edge of the jaw as the width of the interorbital space, which is about as wide as the diameter of an orbit. The posterior 'table' is flat with decurved lateral edges, which rest in a squamosal suture on the squamosal or quadratojugal and quadrate bones. Its posterior angle is produced downwards and backwards to near the distal extremity of the quadrate. The latter slopes posteriorly and downwards. The quadratojugal region is strongly convex in vertical section. The mandibular ramus is strongly incurved posteriorly, from a point opposite the free extremity of the pterygoid. The symphysis mandibuli is short.

"The sculpture is distinct on all the superior surfaces of the skull, and consists of fossæ of medium size, bounded by irregular, narrow ridges. There are three fossæ in 10 mm. The fossæ are obsolete on the extremity of the muzzle and on the anterior part of both jaws.

"The teeth are a little longer on the premaxillary than on the maxillary bone. There are five on each, or six, if the tooth below the nostril belongs to the premaxillary bone. The palatine teeth are much larger. The first, perhaps standing on the external edge of the vomer, is a little posterior to the line of the external nostril. The second is half-way between the nostril and orbit, and the third is alongside of and just posterior to it. The fourth is opposite a point a little posterior to the middle of the orbit. Their surface is as yet obscured by a thin layer of fine indurated mud, which in some instances can not be removed without destruction of the tooth surface.

"The intercentra of the vertebræ are, as in *Eryops megacephalus*, ossified so as to nearly cut off the chorda dorsalis, but unlike that species they are not notched on one side of their lateral apices. The extremities of the neural spines are subquadrate, rounded behind, and flattened anteriorly. The edges of the postzygapophyses are prominent and flared upwards.

"The scapula is robust and flat, having the posterior-external border longest and concave, and the superior-posterior convex. In my specimens the thin anterior edge is broken. The coracoid appears to be coossified with the proximal external edge of the scapula and is directed downwards and backwards. Its extension is small, and terminates in an apex posteriorly and a thick double edge inferiorly. The glenoid cavity borders this edge and is small. The epicoracoid, if it existed, is lost. The thick, inferior edge of the coracoid and scapula is similar to those of the humerus and vertebral

processes, which suggest a cartilaginous cap. The position of the scapula and coracoid is peculiar. If the glenoid cavity is directed outwards, the ribs adherent to them fit their extremities, from which they have been broken, which adhere to the vertebræ. This is probably the natural position. When thus placed, the plate of the scapula is horizontal transversely and inclined upwards and posteriorly at 30°. The coracoid is vertical. When in place, there is a large tuberosity above and anterior to the glenoid fossa, immediately behind which is a wide, shallow fossa.

"The curve of the proximal extremity of the humerus is a semicircle. That of the distal end is less convex, being flattened at the middle. Viewed proximally, the proximal end is a little concave on one side and one extremity of the articular surface is expanded and rounded. Viewed distally, the distal extremity is angulate concave, the middle portion being straight and the extremities bent in the same direction, one being longer than the other, and neither expanded. The entire extremity makes an angle of 90° with the plane of the proximal end. The epitrochlear foramen is protected by a strong bridge.

"*Measurements.*

"*Skull:*	M
Length to line of angle of mandible	0.188
Length to posterior edge of supra-occipital	.168
Length to line of posterior edge of orbit	.121
Length to line of anterior edge nares	.017
Length to line of extremity of pterygoid	.142
Width of skull at angles of mandible	.134
Width of skull at greatest	.158
Width of skull just behind nares	.051
Width of skull at nares	.051
Width of cranial table at middle	.086
Width between orbits	.030
Length of a premaxillary tooth	.011
Diameter of base of do	.004
Length of a median maxillary tooth	.007
Diameter of base of do	.004
Length of a median palatine tooth	.021
Diameter of same at base	.009
Depth of ramus mandibuli at angle	.015
"*Vertebræ and ribs:*	
Diameters of intercentrum:	
Transverse	.018
Anteroposterior	.010
Total elevation of same vertebra	.027
Elevation of neural spine above postzygapophysis	.005
Total expanse of diapophyses of same	.027

"*Vertebræ and ribs*—Continued.	M
Length of diapophysis from postzygapophysis	.0095
Diameter of end of neural spine	.206
Diameter of end of diapophysis:	
Transverse	.004
Vertical	.006
Length of rib of 5th vertebra in advance of the vertebra measured	.038
Width of rib distally	.027
"*Scapular arch:*	
Length of scapula on anterior face	.069
Width of scapula at antero-internal distal angle, transversely	.032
Width of coracoid and epicoracoid at glenoid cavity, from edge of scapula	.023
Length of epicoracoid and coracoid	.037
Length of humerus	.064
Width of shaft at middle	.016
Diameters proximal end:	
Long	.039
Short at middle	.010
Diameters distal end:	
Long	.039
Short at middle	.010
Length ungual phalange	.004
Length second phalange	.0075
Length first phalange	.0135
Width do:	
Proximally	.010
Distally	.008"

Revised description:

1. Small, not exceeding 500 centimeters in length.
2. Otic notch absent.
3. Orbits of medium size, in middle of skull.
4. Nares near lateral edge of skull, but not terminal.
5. Angle of lower jaw not produced behind quadrate.
6. Lower jaw proportionately as wide as in *Eryops*.
7. Skull with a moderately fine sculpture of pits, uniform in all parts of skull, except at anterior end of jaws, where it is nearly absent.
8. Teeth subequal in size, some, in the premaxillaries, enlarged slightly.
9. Unknown.
10. Unknown.
11. Ribs flattened, expanded at proximal and distal ends but without extension of posterior edge.
12. Unknown.
13. Unknown.
14. Spines of dorsal vertebræ expanded as if in contact with dorsal plate.
15. Humerus short, resembles that of *Eryops* but without well-formed articular ends.
16. Unknown.
17. Unknown.

Family TRIMERORHACHIDÆ Cope.

Am. Nat., vol. XVI, 1882, p. 335; Am. Nat., vol. XVIII, 1884, p. 29.

Original description: In the first paper Cope proposed the order *Rhachitomi* to replace the *Ganocephala* and divided it into two families:

"Occipital condyle concave, undivided..... *Trimerorhachidæ*
Occipital condyle divided into lateral condyles..... *Eryopidæ*"

In the second paper he adds:

"The two families of this order (*Rhachitomi*) are well distinguished by the form of the basioccipital bone. In the Trimerorhachidæ its condyle is simple and concave, somewhat as in some fishes. The Eryopidæ have the two condyles characteristic of the Batrachia generally. This difference might be esteemed as of greater than family significance, but it is less considerable than at first sight appears. The simple, cotylus-like, basioccipital bone of the Trimerorhachidæ is notched above, sometimes deeply, to receive the apex of the notochord. A corresponding notch on the inferior edge would, if present, divide the articulation into two surfaces, which would greatly resemble the condyles of *Eryops*. The latter are flat and look partly towards each other, and are evidently separated originally by the *fissura notochordæ*."

Revised description:

1. Small. Not exceeding 500 centimeters.
2. Occipital condyles united.
3. Otic notch small.
4. Parasphenoid large. Basioccipital not apparent.
5. (Two functional sacral ribs?)
6. No dermal armor on back.

7. Clavicle and interclavicle with external sculpture (?).
8. Unknown.
9. Humerus small, without condyles. Articular ends nearly parallel, without prominent processes.
10. Femur without ridge on ventral surface.
11. The two halves of the neural spine still separate.
12. Intercentrum very thin, leaving large notochordal space.

Genus TRIMERORHACHIS Cope.

Proc. Am. Phil. Soc., vol. XVII, 1878, p. 524; Proc. Am. Phil. Soc., vol. XIX, 1880, p. 54; Am. Nat., vol. XVIII, 1884, p. 32.

Type: A fragmentary skull with a series of vertebræ. No. 4565.

Paratype: A skull No. 4557, Am. Mus. Nat. Hist. Cope Coll. From Texas.

Original description: In the first paper Cope gave the following:

"*Char. Gen.* The centrum is represented by three cortical ossifications of the chorda-sheath, a median inferior, and two lateral. The lateral pieces are quite distinct from each other, and are in contact with the neurapophyses above and the posterior border of the median segment in front. The neural arch joins chiefly the lateral elements, but is in slight contact with the lateral summits of the inferior element. The halves of the neural arch are coossified and support well-developed zygapophyses, but no neural spine. A lateral expansion of the base of the neurapophyses represents the diapophysis, but it is horizontal and thin.

"The cranial bones are sculptured with pits and reticulate ridges. The parasphenoid bone is flat. The external nostrils are large and superior, and not anterior. The angle of the mandible is little produced, and the glenoid cavity is transverse and wider at the inner than at the external extremity. The inner wall of the mandible descends from the glenoid fossa, including, with the horizontal outer wall, a deep internal pterygoid fossa. No coronoid bone or process. Symphysis short.

"The teeth exhibit the inflected dentine of this and allied groups. So far as preserved, they are simply conic, but there are none with the apices complete. There are two series on each side of the upper jaw, both of which consist of larger teeth at their anterior portions. The anterior teeth of the inner row beneath the external nares are much the largest. A thin, bilateral bone from some part of the roof of the mouth supports some large teeth, and a row of small ones diverging from them on each side. The mandibular teeth are in one principal series and become a little larger anteriorly. Near the symphysis there are on each side, within the external row, one or two large teeth. The ribs are short and little curved, and they have flat, expanded heads. They are attached to the diapophysial expansion of the neural arch. Such limb bones as are preserved are without condyles, and are of relatively small size.

"*Trimerorhachis* differs from *Archegosaurus* in the ossification of the basicranial elements; in the absence of attached neural spines; and in the regular and definite tripartite ossification of the chorda-sheath. The form of the cranium of *Trimerorhachis* is unknown."

In the second paper cited Cope added considerably to his previous description:

"*Generic characters*, etc.: The type of skull is that of the order of *Stegocephali* generally. The superior walls are thin, and are sculptured on the

superior surface. The mucous grooves are distinct, but do not form a well-defined lyra. There is a groove which is parallel to the anterior borders of the orbit for a short distance, and which then turns forwards and then inwards. The dermal ossification is distinguished from that of the maxillary bone by a squamosal suture. A mucous groove descends to it obliquely forward from the superior quadrate region, and sends a branch at right angles to its anterior extremity to a point posterior to the orbit. Of superficial ossifications, the boundaries are difficult to determine, owing to the obscurity of the sutures. Enough can be seen to demonstrate the presence of supramaxillary, epiotic, and supraoccipital dermal bones. The nostrils are large and well separated, and look upwards.

"The teeth are acute and of subequal size; their superficial layer is deeply inflected at the base.

"The parasphenoid bone is wide posteriorly, but contracts abruptly and extends forwards on the middle line. Owing to the crushing of a part of the surface, I am unable to ascertain its anterior or vomerine suture. The basifacial axis bone is quite narrow and is edentulous. It is connected with the superior cranial walls by a vertical osseous plate on each side, which may represent alisphenoid, orbitosphenoid, and ethmoid. The palatopterygoid arch is a longitudinally extended sigmoid, enclosing, with the axial elements, an enormous, choanoörbital foramen. It extends from the middle line below a short distance posterior to the position of the nostrils outwards, and follows closely the maxillary bone well posteriorly. It then turns inwards, extending to the parasphenoid bone, with the wide portion of which it has an extensive contact. It then turns outwards as pterygoid bone and, rapidly narrowing, joins the inner distal extremity of the quadrate. It thus incloses a foramen with the quadratojugal bone, which is much smaller than the choanoörbital foramen. The posterior part of the inferior surface of the bones of this arch, not including the slender pterygoid portion, is roughened with hard nodules resembling teeth in material, and serving the purpose of such organs.

"Two rod-like bones extend outwards and backwards from the posterior part of the parasphenoid and the basioccipital, which belong to the inferior arches. The anterior is the larger and is bent backwards at an obtuse angle; its proximal extremity is a truncate oval. This bone occupies the position of the stapes. The second is extensively in contact with the basioccipital by its proximal extremity. It is curved backwards at its distal third. The occipital condyle is represented by a fish-like cotylus, which has a deep notch at its superior border.

"The mandible has a short, angular process, vertical by lateral compression. The symphysis is very short and the Meckelian cavity large and completely inclosed.

"The anterior, cervical vertebræ consist of the same elements as the dorsals. The intercentra of the second and third vertebræ support capitular costal articulations, somewhat elevated above the surrounding level. The pleurocentra do not support the ribs, but the neural arches terminate below in diapophyses. There is a pleurocentrum in front of the second intercentrum, and above and in front of it a neurapophysis, which has no distinct diapophysis. Its superior portion is a subacute process which is not in contact with that of the other side, but is separated from it by a vertical osseous plate, which is probably the neural spine of the second vertebra

or axis. This is similar to the structure already observed in *Eryops* and, the parts being in place, should explain those of that genus. The portion of the atlas which represents the intercentrum is divided into two lateral portions, each of which has the form of an entire intercentrum, *i. e.*, crescentic. The intercentrum of a cervical of a large species of this group is wider than that of the other vertebræ and presents two articular facets anteriorly."

In the "American Naturalist" he adds:

"This genus presents the most imperfect vertebræ known in the order (*Rhachitomi*). It differs from all others, including *Archegosaurus*, in the lack of a distinct neural spine. Its humeri do not display condyles, but had cartilaginous articular surfaces. The teeth are rather small and of equal size, except a large one or two inside the external series near the anterior part of the mouth."

Revised description:

1. Small, not exceeding 500 centimeters in length.
2. Skull elongate, flat; orbits small, in anterior half of skull; without elevated rims; no interorbital depression.
3. Nares not terminal.
4. No preorbital depressions.
5. Sculpture finely reticulate; edges of skull smooth.
6. Tabulare not prolonged into points. Posterior edge of skull not deeply concave.
7. Occipital condyle not divided.
8. A double row of teeth on maxillary. Teeth not enlarged, except on anterior end of mandible, and palatine tusks (?).
9. Intercentra thin, not constricting the notochord.

Trimerorhachis insignis Cope.

Cope, Proc. Am. Phil. Soc., vol. XVII, 1878, p. 524; Proc. Am. Phil. Soc., vol. XIX, 1880, p. 54; Proc. Am. Phil. Soc., vol. XX, 1883, p. 630.
Broili, Paleontographica, Bd. LI, 1904, p. 39.

Type and paratype: The same as the genus.

Original description: "There are two large tusks at the anterior extremity of the inner superior row of teeth, and two similar ones on the plate-like element above described (see description of the genus). The inferior border of the mandible rises gradually posteriorly to below the posterior border of the glenoid cavity, behind which it is a short vertical and compressed angular process, which is rounded in profile. There is a patch of small teeth inside of the posterior extremity of the mandibular series. The mandible closes inside of the posterior part of the quadratojugal arch. There is a groove near the inferior margin of the inferior face of the mandible; external to this the surface is marked with elongate, shallow pits. The sculpture of the external side of the ramus is less pronounced, and the pits are smallest near the angle. The pits of the top of the cranium are coarse and well defined. The fragment of maxillary bone is broken off four teeth behind the tusks, and the neural opening has contracted but little at that point. The sculpture of the anterior portion of the maxillary is coarsely reticulate.

"The diapophyses of the centrum are oblique rhomboids in form, the anterior upper side receiving the neural arch. The external surface is concave and smooth. The median element, which I call the intercentrum, is a

crescent with subacute horns, which terminate below the anterior part of the posterior zygapophyses. The inferior surface is slightly angulate, with two low, latero-inferior ridges, and sometimes a low median one. The surface between them is delicately reticulately sculptured. The neural arch is oblique and highest behind. The combined neurapophyses rise rather abruptly behind the anterior zygapophyses with an obtuse and convex margin. They then descend in an arc to the extremities of the posterior zygapophyses, diverging downwards and separated by an open groove, which was doubtless the basis of attachment of the cartilage which represented the neural spine. External surface of the neurapophyses smooth. The zygapophyses have little lateral expansion, but are well defined and prominent antero-posteriorly. The processes which I have alluded to above as diapophyses may not be such, as they are simply transverse expansions of the anterior portion of the neurapophyses, whose posterior border articulates with the lateral diapophyses of the centrum.

"The basioccipital condyloid fossa is transversely hexagonal in outline, the superior border being deeply notched by the superior portion of the *fossæ chordæ dorsalis*. The articular surface itself is funnel-shaped. The parasphenoid bone advances far posteriorly under the basioccipital. It expands into an acute angle on each side below the prootic, and then contracts, so that its sphenoid region is narrower than its occipital extremity. Its surface is slightly concave.

"*Measurements.*

	M		M
"Depth of the maxillary bone at the middle of the nares	0.021	Six posterior mandibular teeth in.	.011
Width of the palatal surface at middle of the nares	.014	Transverse extent of glenoid cavity	.012
Six maxillary teeth at middle of nares	.014	Transverse diameter of condyloid fossa of occiput	.019
Diameters of an anterior maxillary tooth	.002	Vertical diameter of do	.013
Diameters of an anterior tusk of the inner row	.004	Greatest width of parasphenoid	.034
Length of ramus mandibuli to anterior border of interna pterygoid fossa	.058	Thickness of do. at sphenoid portion	.0035
Depth of do. at do	.023	Three vertebræ (measured below) in.	.042
Length of ramus mandibuli to posterior border of internal pterygoid fossa	.015	Chord of intercentrum	.018
Depth of ramus mandibuli at do	.016	Length of intercentrum below	.010
Depth of ramus mandibuli 0.110 from angle	.016	Thickness of intercentrum below	.002
		Total length of neural arch	.017
		Elevation of do. above posterior zygapophyses	.008
		Expanse of anterior zygapophyses.	.007
		Long diameter of lateral diapophysis	.012
		Short diameter of lateral diapophysis	.005
		Length of rib	.021
		Width of head of do	.008"

In the second paper Cope adds the description of the head: "The skull is flat and rather wide, the length exceeding a little the transverse posterior diameter. The posterior borders of the orbits mark a point half-way between the extremity of the muzzle and the posterior supraoccipital border. The orbits themselves are of medium size and are separated by a space about equal to their transverse diameter. Their form is a wide oval, with the long axis obliquely anteroposterior. The diameter of the external nostril is nearly half of that of the orbit, and the form is similar to that of the latter. The interorbital and ethmoidal regions are concave; the prefrontal

regions are convex. The supraoccipital border is strongly concave; and the notch separating the epiotic angle from the quadrate angle is as deep as the supraoccipital. The surface of the cranium is thrown into wrinkles with no regular pattern and which inosculate to a moderate extent, most so on the preorbital region. The anterior parts of the maxillary and mandibular bones are marked with small, pit-like impressions.

"*Measurements.*

	M
"Total length to quadrate angles measured on the median line...	0.170
Length to supraoccipital border.....	.138
Total width posteriorly.....	.155
Width at orbits.....	.095
Width between orbits.....	.021
Width at nares.....	.062
Width between nares.....	.030
Long diameter of orbits.....	.026
Transverse diameter of occipital cotylus.....	.012"

See also the description of *T. bilobatus.*

Revised description: This is contained in the revised description of the genus.

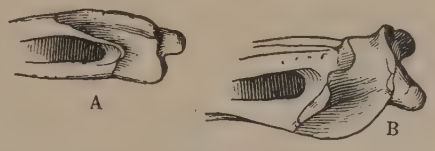


FIG. 5.—Upper view of articular region. × ¾.
A. *T. insignis.* No. 4565 Am. Mus.
B. *T. bilobatus.* No. 4562 Am. Mus.

Table showing distinction of the species T. insignis, T. bilobatus, and T. mesops.

T. insignis: Posterior angle of the jaw composed of a single tuberosity, an outer tuberosity indicated by a small protuberance. Skull somewhat expanded posteriorly. Orbits in anterior half of skull.

T. bilobatus: Posterior angle of jaw formed by two subequal tuberosities separated by a deep groove. Inner side of inner tuberosity vertical with a strong horizontal keel.

T. mesops: Inner side of inner tuberosity continued inward horizontally, no keel. Skull not expanded posteriorly. Orbits almost exactly in middle of skull.

Trimerorhachis bilobatus Cope.

Proc. Am. Phil. Soc., vol. xx, 1883, p. 629.

Type: The angle of a mandible. No. 4562 Am. Mus. Nat. Hist. Cope Coll. From Texas.

Original description: "Among the many specimens of animals of this genus which have passed through my hands, I have not until now been able to select more than one species, the *T. insignis.* Mr. Cummins, however, now sends me parts of skeletons of four individuals, which present distinctive characters. Two of these include vertebral elements, and all embrace jaws and bones of the limbs and arches.

"The vertebræ present no important difference from those of *T. insignis,* but the surface of the intercentrum is not yet cleaned of a thin layer of matrix. The peculiar character of this species is most readily seen in the posterior portions of the mandibular ramus. The angle consists of two sub-

equal tuberosities which are separated by a deep groove instead of one prominent one. The external tuberosity is represented in the *T. insignis* by a small protuberance of the lateral enlargement of the external face of the ramus. The extremity of this tuberosity is in the *T. bilobatus* strongly honeycombed, and it is bounded below and externally by a groove which is faintly indicated in *T. insignis*. Above it, on the inner side, is another shallow groove, from which it is separated by a sharp ridge. Both grooves are smooth. The superior one is wanting in *T. insignis*. The quadrate cotylus is more depressed externally than in *T. insignis*, thus making it more oblique. The internal fossa of the cotylus is not divided by a longitudinal groove, as it is in *T. insignis*. The dental foramen is large and is located as in the *T. insignis*. There is also an inferior longitudinal groove of the ramus as in that species. The surfaces preserved show that the sculpture is more marked in the *T. bilobatus* than in the *T. insignis*.

"*Measurements.*

	M
"Depth of ramus at interior edge cotylus	0.026
Length of ramus from interior edge cotylus	.020
Width of ramus at interior edge cotylus	.017
Width of both tuberosities of angle	.0125
Diameters of intercentrum:	
Anteroposterior	.011
Transverse	.021
Thickness of intercentrum	.004"

Revised description: See table in revised description of *T. insignis* above.

Trimerorhachis conangulus Cope.

Proc. Am. Phil. Soc., vol. xxxv, 1896, p. 137.

Type: An imperfect skull. No. 4569 Am. Mus. Nat. Hist. Cope. Coll. From Texas.

Original description: "Size, the least of the species of the genus. Angle of the mandible produced, conic. Orbits rather large, the posterior border nearer the line of the end of the muzzle tnan to the posterior extremity of the mandibular angle, but not so near as to the posterior border of the tabular bone. External nares half-way between the orbit and the end of muzzle. Interorbital width equal diameter of orbit.

"Teeth small, the crowns elongate and acute. Twenty-two may be counted from the posterior end of the series to a point opposite the anterior border of the orbit. A much larger tooth is situated on the external border of the maxillopalatine (vomer), a little distance in front of the choanæ, while an equally large one is situated directly on the posterior border of the latter. Another tooth of equal size is situated external to the posterior tooth, near the maxillary border, and the base of a smaller one is visible beneath the two.

"The mandibular ramus becomes quite slender anteriorly. Posteriorly, the sutures of the angular, articular, dentary, and splenial are distinct. The symphysis projects beyond and turns up in front of the premaxillary border. The angle projects considerably beyond the quadrate, and is rounded below and at the sides. The extremity is vertically grooved, but whether accidentally or normally I can not determine.

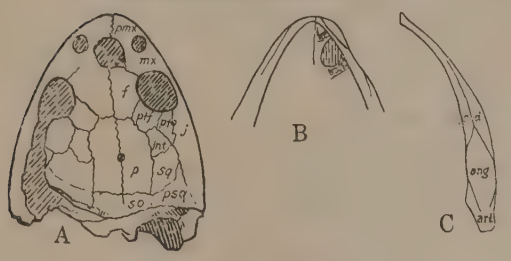
"The elements comprising the cranial roof are mostly distinguishable. The supraoccipitals have considerable extent on the superior face of the skull. The largest bones are the parietals, whose median suture is inter-

rupted by the foramen at about the middle. The next largest bone is the tabular, which extends half the length of the parietal forwards. The supramastoid is pyriform, is rather small, and its anterior angle is wedged in between the posterior parts of the postfrontal and postorbital. The postfrontals separate the frontals from the orbital border. The frontals are distinct and their posterior border is about in the line of the posterior borders of the orbits. The supratemporal region is injured, and only the suture between the quadratojugal and the jugal is visible.

"The sculpture consists of radiating ridges from some point in each bone to its circumference. This point may be near the center or one of the borders of the bone. The ridges may be more or less interrupted or inosculating. They are present on the lower jaw as well as on the upper.

"*Measurements.*

	MM
"Length of skull on base including symphysis	40
Width of skull at quadrate articulations	36
Length of mandibular angle from do	6
Transverse diameter of orbit	5
Length from posterior border of skull to orbit	18
Width between nostrils	10"



A. Upper view of type skull showing sutures. *pmx*, premaxillary; *mx*, maxillary; *f*, frontal; *ptf*, postfrontal; *pto*, postorbital; *j*, jugal; *p*, parietal; *int*, intertemporale; *sq*, squamosal; *psq*, prosquamosal; *so*, supraoccipital plate. The opening in the middle line of the nose is a break.

B. Diagram of lower surface of anterior end of nose, showing enlarged vomerine and palatine teeth.

C. Diagram of lower jaw. *d*, dentary; *s*, splenial; *ang*, angular; *art*, articular.

FIG. 6.—*T. conangulus*. No. 4569 Am. Mus. × ⅓.

Revised description: Smallest of the genus. Skull not so flat in the postorbital region. Intertemporal present. Doubtfully a *Trimerorhachis*.

Trimerorhachis leptorhynchus Case.

Second Ann. Rpt. Dept. Geol. and Nat. Hist. Territory of Oklahoma, 1902–3, p. 64.

Type: An imperfect skull. No. 350 University of Kansas. From northwest of Orlando, Oklahoma.

Original description: "A somewhat crushed skull indicates the presence of a new species. The skull is imperfect, having lost the anterior end of the muzzle and a portion of the articular region of the left side. The whole skull is much longer and more slender than any known species of this genus, its proportions being more those of *Cricotus* than *T. insignis*. The teeth are mostly hidden, but one or two show that they are small and fine. The orbits are directed more upwards than laterally and they were of greater anteroposterior extent than lateral. The quadrate region of the skull projects quite far behind the articular portion (cotylus) so that there is a very prominent excavation of the posterior portion of the skull. The ends of the mandibles do not project posterior to the quadrate. The mandibles approach each other, to contact in the posterior third of their length. The outer side of the mandible is marked by longitudinal lines of sculpture. The whole skull contracts sharply anterior to the occipital region, about opposite the orbits.

"*Measurements.*

	M
"Width of the skull at the quadrate region	0.038
Width of the skull opposite the orbits	.030
Projection of the quadrate region beyond the midline of the skull	.013
Length of the incomplete skull (about .01 or .02 m. missing)	.052"

Revised description: This species was founded on a very imperfect fragment of a skull. I am unable, with fuller knowledge, to identify it as belonging to *Trimerorhachis*. It must be dropped as indeterminate. Further knowledge may show that the type is a fragment of a skull of the genus *Cricotillus* Case.

Trimerorhachis mesops Cope.

Proc. Am. Phil. Soc., vol. xxxiv, 1896, p. 454.

Type: An imperfect skull and a good portion of the vertebral column. No. 4568 Am. Mus. Hist. Cope Coll. From Texas.

Original description: "The greater part of the skull and vertebral column with ribs and thoracic plates represent this species. The vertebral column and ribs rest in a sheet of matrix whose upturned edges suggest that it contains as a support a ventral armature. It also looks like a cast of a cavity left in the matrix by the dissolution of the inferior body wall. The only part of the vertebræ discernible without further cleaning are the neural arches. Limbs not detected. The posterior border of the skull is damaged, but one angle is preserved and all of the other but the apex. The remainder is in good preservation on one side or the other, and the surface has been cleaned by weathering. The lower jaw is tightly closed on the upper.

"The skull does not expand posteriorly as in the *T. insignis*. The posterior border of the orbit is 4.5 times the diameter of the latter in front of the angle of the mandible, and four times posterior to the line of the end of the muzzle. It is thus nearly in the middle of the length of the skull and posterior to the position it holds in the *T. insignis*. The interorbital space is nearly twice as wide as the diameter of the orbit, while in *T. insignis* it equals that diameter. The muzzle is therefore relatively elongate, and it projects an eye diameter beyond the line connecting the anterior borders of the nostrils. The latter are large and look upwards; and the long or anteroposterior diameter equals the transverse diameter of the orbit. There are no preorbital or interorbital depressions. The sculpture is strongly marked. On the jaws it is generally longitudinal; on the supratemporal, radiating; on the top of the front and muzzle, reticulate with some predominance of the longitudinal ridges. The sensory grooves are very obscure, but are traceable on the internal borders of the nostrils, but scarcely posterior to them. The groove on the internal side of the inferior border of the mandibular ramus is distinct. The rami are more transversely expanded than in the specimens of *T. insignis*, but some of this may be distortion due to pressure. The parasphenoid is narrow for the greater part of the length.

"The *T. bilobatus* is known from the angles of the mandible of two individuals, and probably by associated remains. The corresponding parts of the *T. mesops* are much more expanded transversely inwards, are horizontal in fact where the inner wall is, in the *T. bilobatus*, vertical. The strong internal keel of the latter, if represented at all in the *T. mesops*, has an external position.

"The neurapophyses of the vertebræ are more elevated and more delicate than in the *T. insignis*, and have the usual median longitudinal groove between them on the median line above.

"The thoracic shield is represented by a coarsely sculptured plate which is but partially exposed, so that its form is as yet uncertain.

"The species is smaller than the *T. insignis*.

"*Measurements.*

	MM
"Length of skull to line of mandibular angles	136
Width of skull at line of mandibular angles	100
Length from orbit to end of muzzle (axial)	47
Interorbital width	25
Internarial width	29
Diameter of orbit	12
Width of mandible at quadrate	25
Length of four vertebræ over the arches	30"

Revised description: See table in revised description of *T. insignis*, p. 43.

Trimerorhachis alleni.

Bull. Am. Mus. Nat. Hist., vol. XXVIII, art. XVII, 1910, p. 181.

Type: Four dorsal vertebræ. No. 4577 Am. Mus. Nat. Hist. Cope Coll. From Texas.

FIG. 7.—*T. alleni.* No. 4577 Am. Mus. × ¾.
Four dorsal vertebræ, from left side.

This specimen differs from the type specimen in such important respects that it is necessary to regard it as a new species. The vertebræ are larger than in any of the typical specimens, four intercentra occupying 166 mm. The neural spines show little indication of being divided, but the tops of the spines are still concave and show the former presence of a considerable mass of cartilage. The pleurocentra are proportionately very small. The spines are more erect and there are well-formed posterior zygapophyses. The intercentra are marked on the lower face by deep pits lying on either side of a median keel. The posterior edges of the upper ends of the intercentra are reflected forward and form a concave facet.

Genus ZATRACHYS Cope.

Proc. Am. Phil. Soc., vol. XVII, 1878, p. 523; Am. Nat., vol. XVIII, 1884, p. 36.

Type: Lost.

Neotype: An imperfect skull with numerous fragments. No. 4589 Am. Mus. Nat. Hist. Cope Coll. From Texas.

Original description: "*Char. Gen.* The existence of this genus is demonstrated by various fragments, the most characteristic of which is a portion of a maxillary bone. This probably belonged to a species of the order *Stegocephali*, but whether to the Ganocephalous or Labyrinthodont division is uncertain, though the evidence is in favor of the former. The teeth are in

a single series, and their bases are anchylosed to the bottom of a shallow groove. The external boundary of this groove is more prominent than the internal, so that the attachment of the teeth is shortly pleurodont. The teeth have conic crowns, and have basal grooves indicating the dentinal inflexions common to this group. The maxillary and other bones are characterized by their strong sculpture, in the former the ridges being developed into prominent tubercles in various places."

In the "American Naturalist" Cope added:

"The genus was originally represented by a maxillary bone, which supports teeth of unequal length, and whose surface is extraordinarily rugose. In the typical species, *Z. serratus*, the rugosities project in the form of teeth along the external alveolar border. Individuals with sculptured neural spines and dermal bones are referred here. The intercentra are much like those of *Eryops* and *Acheloma*."

Revised description (skull only known):

1. Small, not exceeding 500 centimeters in length.
2. Skull less elongate; elevated in orbital region. Orbits in posterior third of the skull; rims elevated, a strong interorbital depression.
3. Nares far back.
4. Deep preorbital depressions.
5. Sculpture not certain, surface destroyed in specimens preserved. Bones show a strong radial structure. Sutures very complicated, long processes from edges of bones, interlocking strongly.
6. Tabulare prolonged into points. Posterior edge of skull more deeply concave.
7. Occipital condyle divided.

Zatrachys serratus Cope.

Z. serratus, Proc. Am. Phil. Soc., vol. XVII, 1878, p. 523.
Z. micropthalmus Cope, Proc. Am. Phil. Soc., vol. XXXIV, 1896, p. 452.

Neotype of *Z. serratus* the same as the genus.

Type of *Z. micropthalmus*, a skull No. 4586; *paratype*, a skull No. 4587 Am. Mus. Nat. Hist. Cope Coll.

Original description of Z. serratus: "The horizontal expansion of the maxillary bone is a character of this species, so that its plane forms an obtuse angle with that of the long axes of the teeth. It presents no palatal lamina. The teeth are separated by intervals of greater width than the diameter of the base. The border of the bone above the teeth is thickened, and the ridges are developed into numerous tubercles. These project externally so as to form a prominent serrate margin entirely overhanging the external alveolar border. The ridges diverge inwards in a radiating manner. The surface is otherwise irregular from the presence of a deep fossa on the outer side within the inner alveolar border.

"*Measurements.*

	M
"Length of fragment	0.018
Width of fragment	.018
Width of fragment, alveolar groove	.002
Length of prominences beyond alveolar border	.003
Diameter of a tooth basis	.001
Three teeth in	.005"

Original description of Z. micropthalmus: "Represented by an entire skull covered with a thin layer of bean ore, and a second and larger skull without lower jaw and with the extremity of the muzzle broken off. The second specimen displays the characters of the base of the skull, and in other respects better displays the specific characters.

"The attenuation of the bones of the skull exhibited by the *Z. serratus* is present in this species also. The interorbital and preinterorbital regions are strongly concave, and there are strong preorbital fossæ. The tabular angles are very prominent, forming rudimentary horns, and there is a prominent angle projecting from the posterior quadrate region. What especially characterizes this species is the small size of the orbits. These are about half the diameter of those of a *Z. serratus* of the same size, and are half the diameter of the space between their posterior border and that of the cranium at the middle line, and enter the interorbital width 2.5 times. The posterior border of the orbit marks the fourth fifth of the length from the end of the muzzle to the middle supraoccipital border. The muzzle narrows rapidly anteriorly, presenting an elliptic outline, and is much depressed.

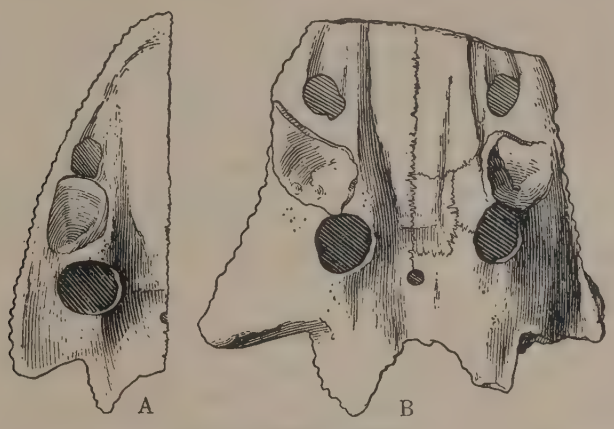


FIG 8.—*Zatrachys serratus.*
A. Left half of a skull with antorbital fossa freed from matrix. No. 4586 Am. Mus. × $\frac{3}{5}$.
B. Upper view of skull. Antorbital fossæ are still filled with matrix. No. 4587 Am. Mus. × $\frac{3}{5}$.

"The parasphenoid bone widens anteriorly so that the pterygoid foramina are triangular with the base posterior and the apex anterior. At the extremities of the transverse processes of the parasphenoid the pterygoids send a prominent border downwards; they then curve rather abruptly outwards to the quadrates. The teeth have not been fully exposed, but on the middle of the length of the maxillary bones they are small and widely spaced.

"*Dimensions.*

"No. 1.	MM
Total length on middle line	100
Width at orbits	84
No. 2.	
Width at orbits	96
Width between extremities of quadrates	130
Width between tabular horns	21
Width between orbits	27
Length from orbit to extremity of tabulare	40

"It is uncertain whether there is a process at the inner side of the tabulare as in *Z. serratus*. The region of the occipital condyle is without projection and is like that of other species of the genus."

Revised description: This is contained in the description of the genus. The two species are indistinguishable in the known specimens. The difference in size of the orbits mentioned by Cope is not apparent after the specimens have been cleaned. There are more prominent serrations on the supraoccipital plate of the specimen called *Z. serratus*, but their absence from other specimens may easily be the result of conditions of fossilization.

Zatrachys conchigerus Cope.

Proc. Am. Phil. Soc., vol. xxxiv, 1896, p. 453.

Type: The posterior portion of a small skull. No. 4590 Am. Mus. Nat. Hist. Cope Coll. From Texas.

Original description: "This ganocephalous batrachian is known to me from the posterior part of the cranium of an individual about the size of the smaller specimen of the species just described (*Zatrachys micropthalmus*). It differs from this and from the *Z. serratus* in two conspicuous characters. First, the tabular processes are smaller and more widely separated from each other; second, the border of the quadratojugal element projects freely from the distal part of the quadrate, and is separated by an open emargination. The orbits are not so small as in *Z. micropthalmus*, have a raised border, and are posteriorly placed. Their diameter is about equal to the space between their posterior border and the tabuloquadrate notch, and is about half the interorbital width. The tabular processes are quite small, and the border connecting them is depressed in the center. The surface is strongly rugose.

"The occipital condyles are represented by two shallow cotyli, which are confluent on the middle line. The posterior part of the pterygoid forms a sharp curve inwards before reaching the quadrate, and presents a thin edge inferiorly. The free edge of the quadratojugal is serrate. The muzzle of this specimen is broken off a short distance anterior to the orbits.

"*Dimensions.*	MM
"Width at quadrates	56
Width at quadratojugals	74
Width between orbits	20
Width between tabular processes	25
Diameter of orbit	10"

Revised description: This poorly preserved fragment shows only that portion of the skull posterior to the orbits, and is covered with a hard matrix. The orbits are in the same relative position as in *Zatrachys serratus*. The posterior ends of the tabulare are broken off and so the length can not be given. There is a deep emargination of the posterior separating off the quadratojugal; this is apparently natural, but the condition of the specimen makes it impossible to determine whether the bones have been broken or not.

The species is indeterminate and must remain doubtful until further information is gained by discovery.

Zatrachys apicalis Cope. (See *Aspidosaurus apicalis* Cope, page 65.)

Zatrachys crucifer Case. (See *Aspidosaurus crucifer* Case, page 66.)

Genus TERSOMIUS Case.

Tersomius texensis Case.

Bull. Am. Mus. Nat. Hist., vol. XXVIII, Art. XVII, 1910, p. 180.

Type: A skull. No. 4719 Am. Mus. Nat. Hist. From Texas.

Original description: "The skull is flattened, having nowhere near so much of an arch as in the specimen described by Cope as *Trimerorhachis conangulus*. The orbits are large, extending so close to the edge that there is a very thin maxillary border. The nares are small and look almost directly upward. The teeth are small and sharply conical with no enlarged ones visible in the maxillary or the mandible. The position and relations of the various bones are shown in the figure. There is no tabulare visible and it is probable that it was not present. Compared with *Trimerorhachis conangulus*, which it most resembles, there is no second prosquamosal (intertemporale) and the orbits are much larger and placed farther to the rear.

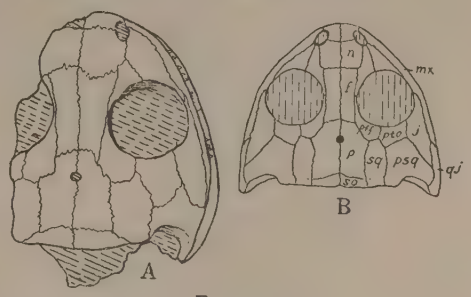


FIG. 9.
A. *T. texensis.* No. 4719 Am. Mus. × 1.
B. Restoration of skull. Lettering as usual. × ½.

	MM
"Length on the median line	32
Length of the lower jaw	34·5
Width at the back of the skull	25
Interorbital width	7"

Revised description: No change from the original.

Family DISSORHOPHIDÆ Williston.

Bull. Geol. Soc. Am., vol. 21, 1910, p. 277.

Original description: The following summary of the *Dissorhophidæ* and the genera *Dissorhophus* and *Cacops* is given by Williston:

"*General characteristics:* Skull with the otic notch completely inclosed to form a large ear cavity. Palate with but two large teeth on each side, one at the anterior inner margin of the nares, the other at the posterior margin; mandibular and maxillary teeth of nearly equal size. Parasphenoid reduced. *Twenty-one presacral vertebræ; two sacral vertebræ; tail short.* A dorsal carapace, composed of lateral expansions of the spines of the vertebræ, with overlying intercalated dermal plates. Cleithrum very large and expanded above. Clavicles small, without exterior pittings. Interclavicle smooth on the dermal surface, small, with a short posterior process. Humerus without ectepicondylar process. Femur with strong adductor crest.

"Genus *Dissorophus* Cope: Dermal carapace extending the full width of the body, with a broad and elongated shield in front, covering several vertebræ. Cleithrum less expanded and thicker. Scapula much expanded antero-posteriorly below.

"Genus *Cacops* Williston: Dermal carapace but little wider than the vertebræ, narrowed in front and not fused into an anterior shield. Cleithrum thin and more expanded. Scapula less expanded below, the interclavicles and clavicles more slender."

Revised description:

1. Small, not exceeding 500 centimeters in length.
2. Occipital condyles separate.
3. Otic notch represented by a large fenestra.
4. Parasphenoid reduced to a slender rod.
5. Two functional sacral ribs.
6. Dorsal armor composed of the laterally expanded neural spines, smooth above and overlain by narrow dermal plates, as wide as the body and alternating with the neural spines in position.
7. Clavicles and interclavicle small, without sculpture.
8. Cleithrum very large.
9. Unknown.
10. Unknown.
11. The two halves of neural arch united.
12. Intercentra thick constricting the notochordal space. No processes on the intercentra for the ribs.

Genus DISSORHOPHUS Cope.

Cope, *Dissorhophus*, Am. Nat., vol. xxix, 1895, p. 998.
Otocœlus, Am. Nat., vol. xxx, 1896, p. 398.
Otocœlus, Proc. Am. Phil. Soc., vol. xxxv, 1896, p. 124.
Williston, *Dissorhophus*, Journ. Geol., vol. xviii, No. 6, 1910, p. 526.

Type: A fragment of the vertebral column. No. 4593 Am. Mus. Nat. Hist. Cope Coll. From Texas.

Original description: The specimen "consists of a portion of the skeleton, which includes ten consecutive vertebræ and their appendages, of the rhachitomus type, similar in general to those of the *Trimerorhachis*. The genus differs from *Trimerorhachis* in this important respect. The neural spines are elevated, and the apex of each sends a transverse branch which extends in an arch on each side of the ribs. These spinous branches touch each other, forming a carapace. Above and corresponding to each of them is a similar, dermal osseous element, which extends from side to side without interruption on the median line, forming a dermal layer of transverse bands which correspond to the skeletal carapace beneath it. To this remarkable genus I propose to give the name *Dissorhophus*. It is a veritable batrachian armadillo."

In the description of the genus *Otocœlus*, Cope says in the "American Naturalist":

"Suspensorium directed anteriorly, except at free extremity; nostrils lateral.....*Otocœlous*
Suspensorium directed posteriorly; nostrils vertical.....*Conodectes*

"*Otocœlous* has the following characters: Intercentra present. Teeth subconical. Mandible not projecting beyond the quadrate. Clavicle expanded at both extremities, overlapping the episternum. Scapula with a proscapular lamina. Ribs transversely expanded, not united by suture with each other, alternating with the dermal bands. Limbs well developed."

In the "Proceedings of the American Philosophical Society" he gave a much fuller description:

"Teeth with subconic crowns. Mandibular ramus not produced posterior to the quadrate. Superior cranial bones strongly sculptured. * * *

There is considerable resemblance between several parts of this animal and those of the stegocephalian Batrachia. This is seen in the forms of the femur and the shoulder girdle, which are similar to those which I have referred to *Eryops*. The close approximation of the huge auricular meatus to the orbit is only seen elsewhere in the anourous Batrachia. The teeth on the other hand are of strictly reptilian type in their mode of implantation, and the lack of dentinal inflections distinguishes them from those of many of the genera of Stegocephalia. There is nothing in the shoulder girdle to distinguish it from the Cotylosauria, and the humerus so far as preserved is of the type of that order. It is impossible to get at the occipital condyles without destroying important parts of the specimen. The vertebræ are amphicœlous.

"It is probable that in life the species of this genus had an enormous tympanic drum.

"The tabular part of the skull is large as compared with the facial part. The posterior border is broken in the *O. testudineus*, but it is continued to a transverse line posterior to the auditory meatus. It was not probably produced into a horn-like process. The suspensorial part of the quadrate is directed posteriorly below. The mandibular ramus has a horizontal expansion of the inner side just anterior to the short angle.

"The clavicles have the distal expansion overlapping the episternum characteristic of the order. The shaft makes an obtuse angle with the expanded portion, and is compressed. Its proximal extremity is expanded into a rounded disk, whose plane is horizontal and at right angles to that of the shaft. Between the shaft and the mandibular angle the edge of the pterygoid is visible. The episternum has the posterior part broken off. The part preserved is a transverse plate, which has, like the clavicles, a smooth surface. The scapula lacks the proximal end. Distally it presents a strong longitudinal ridge which extends to the coracoid. Anteriorly the shaft expands into a procoracoid laminar extension in its plane. The coracoid is small and has a convex internal border, which is not notched as in the Pelycosauria. It may be coossified with the scapula. The humerus has a greatly expanded head and a narrow shaft.

"The femur is longer than the tibia, and displays the condyles characteristic of the Cotylosauria and Pelycosauria. They are unequally produced posteriorly. There is a long and strong anterior crest.

"Two vertebral centra are only moderately well preserved. They are probably anterior dorsals. They are wider than long and are separated by a large and protuberant intercentrum. A free intercentrum of the same shape lies at one side. It is probable that a rather short neural spine rises to the inferior side of the carapace. Only the part next the carapace can be seen in the specimen.

"The ribs are much expanded, but do not touch each other. The carapacial bands alternate with them above, resting on their adjacent edges and separated by narrow interspaces. Towards the supposed anterior part, the superior costal surfaces rise between the carapacial bands to the plane of the latter, forming a closer surface than posteriorly.

"This genus forms a remarkable example of homoplastic resemblance to the rhachitomous genus *Dissorhophus*, which I described in the 'American Naturalist' for November 1895. The superficial resemblance is very great, and it is only after an examination of the constitution of the carapace that the difference of this part of the structure in the two genera is observed.

In the Batrachian genus the ribs are free from and not in contact with the carapace, and the inferior stratum of the latter consists of the expanded neural spines."

Revised description: Cope was in error in his separation of the two forms, *Dissorhophus* and *Otocœlus;* the character of the carapace in both is as described in *Dissorhophus*, and the genus *Otocœlus* is dropped.

1. Small, not over 500 centimeters long.
2. Skull not elongate, elevated, resembling in general proportions that of *Diadectes*. Orbits large, in the middle of the skull, looking laterally. Otic notch represented by a large fenestra.
3. Nares nearly terminal.
4. Parasphenoid a slender rod.
5. One tusk in each prevomer and palatine. Maxillary and mandibular teeth small, sharply conical.
6. ——— ———?
7. Dorsal vertebræ with the neural spines expanded into narrow plates overlying the back. Narrow dermal plates overlying and alternating with the neural spines, extending the full width of the body, with an elongate shield in front covering several vertebræ; rugose above.
8. Ribs double-headed anteriorly; without posterior prolongation.
9. Cleithrum present, less expanded and thicker.
10. Scapula much expanded antero-posteriorly.

Conodectes is distinctly reptilian in the structure of the palate, and has recently been shown by Williston (Journ. Geol., vol. XIX, 1911, p. 232) to be very similar to *Seymouria*.

Dissorhophus multicinctus Cope.

Cope, *D. multicinctus*, Am. Nat., vol. XXIX, 1895, p. 998.
D. articulatus, Am. Nat., vol. XXX, 1896, p. 936, pl. XXI.
D. articulatus, Proc. Am. Phil. Soc., vol. XXXV, 1896, pl. X.
O. testudineus, Am. Nat., vol. XXX, 1896, p. 399.
O. testudineus, Am. Nat., vol. XXX, 1896, p. 936, pl. XXII.
O. testudineus, Proc. Am. Phil. Soc., vol. XXXV, 1896, p. 126.
O. mimeticus, Proc. Am. Phil. Soc., vol. XXXV, 1896, p. 128.
Williston, *D. multicinctus*. Bull. Geol. Soc. Am., vol. 21, 1910, p. 278.
D. multicinctus. Journ. Geol., vol. XVIII, 1910, pp. 525–536.

Type: The same as the genus.

Original description: "As to specific characters it is to be remarked that the intercentra are longer in proportion to their width than in the *Trimerorhachis insignis*. The heads of the ribs have a small, free, truncate angle below their capitulum. The extremities of the transverse processes are free from each other for a short distance, and each has a depressed rounded sharp edge. The dermal bands above them terminate a little proximal of them and in a similar manner, and their extremities are closely appressed to the surface of the band below them, with which they slightly alternate. Their surface is very coarsely rugose, with ridges and fossæ, whose long axes agree with those of the segments. This species I propose to call *Dissorhophus multicinctus*. Length of ten vertebræ in place, 93 mm.; width of intercentrum, 16; length of do., 9; elevation to roof, 30; thickness of carapace, 8; width of a carapacial band, 9; length of do. on curve, 75. This species appeared to have been about the size of the Japanese salamander *Megalobatrachus maximus*."

The name *D. articulatus* was applied to the single specimen by mistake in later publications.

In 1896 Cope gave the description of *Otocœlus testudineus:*

"The skull is short, wide, and flat, and the orbits are large and situated in the auricular excavations. Surface roughly sculptured with small pits and ridges. Malar and mandibular bones shallow. Teeth small, compressed conic, smooth, and without serrations. Scapular arch without sculpture of the inferior surface. Humerus with widely expanded head and narrow shaft. Bands of carapace of moderate transverse extent and roughly sculptured with pits and tubercles. Width between auditory meatuses, 74 mm.; do. between orbits, 32 mm.; do. between auditory sinus and orbit, 16 mm.; transverse diameter of orbit, 28 mm.; width of carapace, 80 mm.; length of clavicle, 80 mm.; transverse width of head of humerus, 35 mm.; length of femur, 67 mm.; length of vertebral centrum, 10 mm.; width of do., 19 mm.; width anterior rib distally, 11 mm."

The species *O. mimeticus* is mentioned but not described in this paper.

A more extended description of the genus appeared in the "Proceedings of the American Philosophical Society" for 1896, in the description of *Otocœlus testudineus:*

"Muzzle very short and broadly rounded. Top of head between and posterior to orbits flat. Orbits directed principally upwards. Intertympanic width 2.5 times interorbital width. Table of skull posterior to orbits about as long as wide. Postorbital width (longitudinal) half as great as interorbital width, which is equal to transverse diameter of orbit. Long diameter of orbit obliquely directed outwards and forwards. Malar bar narrow. Quadratojugal surface posteriorly overhanging border of mandible a little, and these contracted to an apex overhanging angle of mandible posteriorly. Mandibular angle undivided. The superior surfaces of the skull have a strongly impressed honeycomb structure, the ridges between the pits being frequently interrupted. The sculpture extends to the inferior border of the mandible. The pits average 2 mm. in diameter. The sculpture is present on the external surface of the posttympanic hook, where the decurved border is concave. The median parts of the frontal and parietal bones are smooth, but whether this is normal or is the result of weathering I do not know.

"The mandibular ramus presents, a short distance anterior to the angle, a horizontal expansion with a convex border directed inwards and in contact with the pterygoid.

"The crowns of the teeth are acute and smooth. They overlap the edge of the lower jaw and are separated by interspaces equal to their own diameter. They are of quite small size.

"The articular face of the humerus extends downwards on the inner border of the head; perhaps it is restricted to this part of the latter. The section of the shaft is semicircular.

"The fragment which contains the vertebræ, hind leg, and carapace does not form a fit with any fractured face of the mass containing the skull. As, however, everything about the two blocks is harmonious, and as they were found close together, I have no doubt of their pertinence to the same skeleton. The second block is split longitudinally, so that only one-half of the carapace is preserved; but at the supposed proximal end enough of the middle portion remains to include the two vertebræ already described.

A portion of one hind leg, including the distal part of the femur with the tibia and fibula, lies over the carapace externally, while the three principal elements of the other leg lie on the inferior side of the carapace. Both legs are extended in the same direction, *i.e.*, forwards.

"The shaft of the femur has a triangular section, the external face concave owing to the prominence of the anterior crest. The external condyle is produced further posteriorly than the internal, and is a continuation of the general distal surface and is not reflected on the posterior face as in so many of the *Pelycosauria*. The anterior face is flat above and shallowly concave at the condylar border below. The head of the tibia is expanded and the shaft narrowed, as in the *Pelycosauria*. It is straight, while the fibula presents towards it a concave outline; and the two extremities of the latter are about equally expanded.

"The surfaces of the vertebral centra are slightly concave anteroposteriorly. The intercentra are somewhat swollen and knoblike on the inferior face. It is probable that the ribs are less closely adherent to the carapacial bars posteriorly than anteriorly. As already remarked, anteriorly the ribs emerge between the bars to form part of the surface; medially the ribs are below the bars, but touch them. Further posteriorly a cross-section displays a rib which does not touch a bar, except perhaps at the extremity, as the curvature would indicate; but this part is broken off. The superior surfaces of the carapacial elements are of dense bone marked with coarse and fine fossæ and intervening elevations irregularly distributed.

"The size of this animal is about that of the adult of the larger Japanese salamander, *Megalobatrachus*.

"*Measurements.*

	MM
"Width of skull between meatus auditorius	75
Width of skull between orbits	31
Width of skull between orbit and meatus	15
Width of orbit transversely	27
Length of skull above posterior to orbits	65
Depth of malar bone at middle of orbit	12
Depth of mandible bone at middle of orbit	14
Length of tooth external to alveolus	3
Length of clavicle (chord)	78
Widths of clavicle:	
Proximal	22
Median	4
Distal	21
Transverse diameters of humerus:	
Head	35
Shaft	5
Length of femur	67
Anteroposterior diameter of femur:	
Proximally	23
Distally	20
Length of tibia	51
Long diameter of head of do	17
Long diameter of distal end of do	13
Length across the ends of six ribs	75
Length of part of carapace preserved	105
Width of a posterior carapacial bar	10
Width of an anterior carapacial bar	8
Diameters of a vertebra:	
Anteroposterior	8
Transverse	16
Diameters of an intercentrum:	
Anteroposterior	6
Transverse	12"

The species *mimeticus* was described in the same paper:

"This species is represented by a skull with lower jaw in place which is connected by a band of matrix to a carapace, and some of the bones of one of the limbs. Greater and smaller parts of thirteen bands of the carapace are preserved.

"The skull is short and wide. The superior surface is nearly flat from the posterior border to between the nostrils. The muzzle does not project beyond the mouth border. The orbits and nostrils are not superior in direction, although the superior orbital border is excavated. The nostrils are

directed forwards and a little laterally; they are separated by a space equal to the transverse diameter of each. The auricular meatus is large and is directed outwards and not upwards. The posterior hooks of the quadrate project on each side beyond the slightly concave posterior border of the cranial table. Interorbital region flat, considerably wider than the diameter of the orbit.

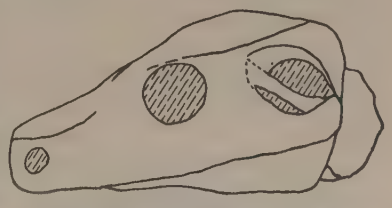


FIG. 10.—*Dissorophus* (*Otocœlus*) *mimeticus*. No. 4376 Am. Mus. × ⅔. Outline of skull, showing closed otic notch.

"The carapace commences at a point about as far posterior to the skull as the posterior border of the latter is behind the orbits. The anterior band has an obtuse anterior border like that of the anterior border of the carapace of an armadillo. The bands are gently convex from side to side, and they become narrower anteroposteriorly as we pass backwards. The state of the specimen is such that neither ribs nor vertebræ can be discovered.

"As compared with *O. testudineus* the following differences appear: The table of the skull projects beyond the posterior hook of the quadrate in the former; not so far in the latter. The auricular meatus and orbit present more laterally in the *O. mimeticus*, more vertically in the *O. testudineus*. The size of the two species is not very different.

"*Measurements.*	MM
"Length of the skull on middle line	120
Width of the skull at posterior border of the orbits	90
Width of the skull between the orbits	38
Width of the skull between the nostrils	22
Length of the skull (median) to anterior border of orbits	78
Distance from skull to carapace	66
Length of thirteen carapacial bands	155
Anteroposterior diameter of first band	17
Anteroposterior diameter of seventh band	12

"The species is named to indicate the superficial resemblance to *Dissorhophus*."

Revised description: There is only one recognizable species, *D. multicinctus;* the revised description is contained in that of the genus.

Following are the original descriptions of the family *Otocœlidæ* and the species *Otocœlus mimeticus* and *O. testudineus*. They are inserted to show Cope's ideas as to their position and relationship.

Family OTOCOELIDÆ Cope.

Am. Nat., vol. xxx, 1896, p. 398; Proc. Am. Phil. Soc., vol. xxxv, 1896, p. 122.

Original description: "Cranial roof excavated laterally behind, forming a large meatus auditorius. Teeth present, in a single row, not transversely expanded. Ribs overlain immediately by parallel, transverse dermoössifications, which form a carapace."

In the "Proceedings of the American Philosophical Society" he gave a much more extended description of the family:

"Posterior border of the roof excavated laterally by the meatus auditorius externus. Teeth present in a single row, not transversely expanded. Ribs immediately overlaid by parallel transverse dermoössifications which form a carapace.

"In the presence of the meatus auditorius this family differs from the other members of the Cotylosauria. In the latter the vestibular space is inclosed by the lateral part of the temporal roof, and has no distal inferior bounding wall. The meatus results in the Otocœlidæ, not merely from the excavation of this roof but also from the excavation of the posterior border of the suspensorium. In *Conodectes* the excavation is not great but in *Otocœlous* it is very considerable, the proximal extremity of the suspensorium having the anterior position seen in the Loricata and the Testudinata. It resembles the quadrate of the latter in the decurvature of the proximal extremity into a descending hook, which partially bounds the meatus posteriorly.

"This meatal excavation constitutes an approximation in the Cotylosauria to other and later orders of the Reptilia, where it is nearly universal. It is interesting to observe that it precedes in time the division of the roof into longitudinal bars by perforation, in the series of which the Otocœlidæ form a part. This fact renders it probable that it is from this family that the Testudinata has descended. The arrangement of the clavicles and episternum is quite like that of the corresponding elements in the anterior lobe of the plastron of the tortoises. The median and posterior part of the abdominal wall of the Otocœlidæ is not known. The teeth are quite insignificant, and their loss would bring us again to the Testudinate type. Their implantation in deep alveoli is reptilian in character. * * *

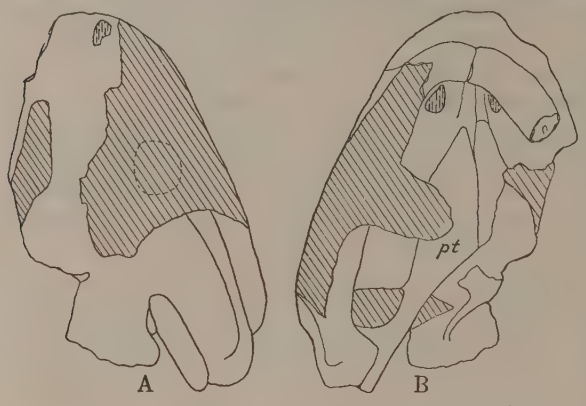


FIG. 11.—*C. favosus*. No. 4342 Am. Mus. × ¾.

A, upper view of skull; B, lower view. Shaded portions restored in plaster. *pt*, pterygoid.

"In this family the slight, posterior concavity of the quadrate region of the Diadectidæ is extended forwards to a great distance, and the osseous tympanum is produced further outwards. The position of the parts is different from that which is characteristic of the Stegocephalia, where the tympanic notch, when present, is superior, owing to the much greater length of the suspensorium. The dental characters also distinguish the family from the Diadectidæ. No ossicula auditus were found in the tympanic cavity."

Genus OTOCŒLUS Cope.

Am. Nat., vol. xxx, 1896, p. 399; Proc. Am. Phil. Soc., vol. xxxv, 1896, p. 125.

Type: Posterior portion of a skull with the pectoral girdle and a part of the carapace. No. 4343 Am. Mus. Nat. Hist. Cope Coll. From Texas.

Original description: Distinguished from the nearly related *Conodectes* by Cope as follows:

"Suspensorium directed anteriorly, except at free extremity; nostrils lateral. *Otocœlous*
Suspensorium directed posteriorly; nostrils vertical ..... *Conodectes*"

The same article gives a further description of the genus:

"Intercentra present. Teeth subconical. Mandible not projecting beyond the quadrate. Clavicle expanded at both extremities, overlapping

the episternum. Scapula with a proscapular lamina. Ribs transversely expanded, not united by suture with each other, alternating with the dermal bands. Limbs well developed."

In the paper in the American Philosophical Society "Proceedings" Cope gives a slightly different analysis of the characters of the two genera:

"Mandible articulated much anterior to cranial border; nostrils opening vertically ..... *Otocœlous* Cope
Mandible articulated posteriorly and on line of the posterior border of the skull; nostrils opening horizontally ..... *Conodectes* Cope"

Otocœlus mimeticus Cope.

Am. Nat., vol. xxx, 1896, p. 399; Proc. Am. Phil. Soc., vol. xxxv, 1896, p. 128.

Type: A skull with the lower jaw in place, which is connected by a band of matrix to a carapace and some of the limb bones. No. 4376 Am. Mus. Nat. Hist. Cope Coll. From Texas.

Original description: "The skull is short and wide. The superior surface is nearly flat from the posterior border to between the nostrils. The muzzle does not project beyond the mouth border. The orbits and nostrils are not superior in direction, although the superior, orbital border is excavated. The nostrils are directed forwards and a little laterally; they are separated by a space equal to the transverse diameter of each. The auricular meatus is large and is directed outwards and not upwards. The posterior hooks of the quadrate project on each side beyond the slightly concave posterior border of the cranial table. Interorbital region flat, considerably wider than the diameter of the orbit.

"The carapace commences at a point about as far posterior to the skull as the posterior border of the latter is behind the orbits. The anterior band has an obtuse, anterior border like that of the anterior border of the carapace of the armadillo. The bands are gently convex from side to side, and they become narrower anteroposteriorly as we pass backwards. The state of the specimen is such that neither the ribs nor the vertebræ can be discovered.

"As compared with *O. testudineus* the following differences appear: The table of the skull projects beyond the posterior hook of the quadrate in the former; not so far in the latter. The auricular meatus and the orbit present more laterally in the *O. mimeticus*, more vertically in the *O. testudineus*. The size of the two species is not very different.

"*Measurements.*	M
"Length of the skull on the middle line	0.120
Width of the skull at the posterior border of the orbits	.090
Width of the skull between the orbits	.038
Width of the skull between the nostrils	.022
Length of the skull (median) to anterior border of the orbits	.078
Distance from skull to carapace	.065
Length of thirteen carapacial bands	.155
Anteroposterior diameter of the first band	.017
Anteroposterior diameter of the seventh band	.012"

Otocœlus testudineus Cope.

Am. Nat., vol. xxx, 1896, p. 399; Proc. Am. Phil. Soc., vol. xxxv, 1896, p. 124.

Type: The same as the genus.

Original description: This is given under the description of the genus *Dissorhophus*.

Genus ALEGEINOSAURUS nov.

Alegeinosaurus aphthitos sp. nov.

Zatrachys, Bull. Am. Mus. Nat. Hist., vol. XXIII, 1907, p. 665.

Type: The anterior part of a skeleton, lacking the skull. No. 4756 Am. Mus. Nat. Hist.

Original description: "The *shoulder-girdle* is complete, but the bones of the right side are in part covered by the bones of the right leg and foot which have been thrown up and back in process of fossilizing.

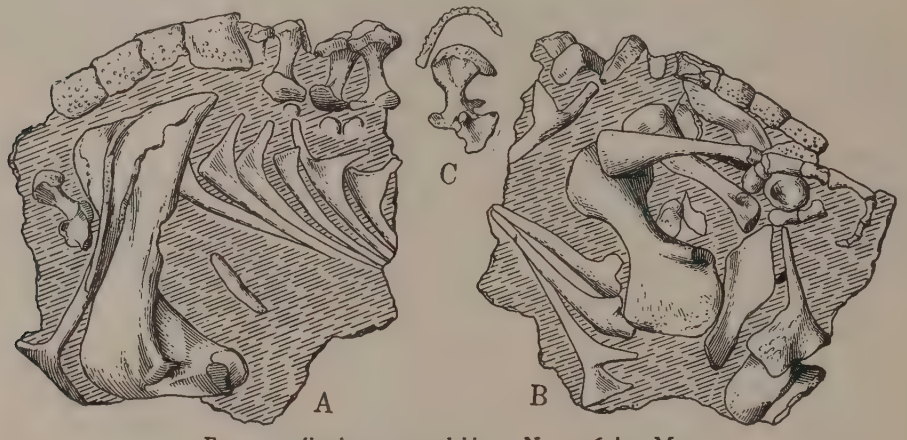


FIG. 12.—*Alegeinosaurus aphthitos.* No. 4756 Am. Mus.
A. A fragment showing clavicle, scapula, cleithrum, and some of the ribs of left side. × ⅛.
B. Left half of same fragment shown in A, showing fore leg and foot. × ⅛.
C. Anterior view of neural spine of a dorsal vertebra with overlying dermal plate. × ⅛.

"The *scapula* resembles that of *Eryops;* the shaft is elongate and slightly broadened at the distal end. There is a deep and well-formed cotylus, but there is no trace of separate coracoid, procoracoid, or epicoracoid.

"The *interclavicle* is roundly shield-shaped, without any posterior prolongation. On the center of the lower face there is a prominence, with articular edges for the inner edges of the clavicles.

"The *clavicles* have the anterior end flat and roughly diamond-shaped, with thin edges. The lower part of the inner edge articulates with the prominence on the lower face of the interclavicle, and the upper part of the edges meet above the articulation with the interclavicle. The shaft is bent at an angle of about 45° to the anterior end. The section of the clavicle is like a capital L turned on its side. The long part of the L lies horizontally and the short part is turned downward and covers the outer edge of the cleithrum. The distal end reaches nearly to the posterior end of the scapula.

"*The cleithrum:* The posterior end is thin, wide, and closely applied to the surface of the scapula; it quickly contracts to a narrow and high ridge on the surface of the scapula near the upper edge. The anterior end extends as far forwards as the cotylus of the scapula.

"The *humerus* has the form common to the amphibia of the Permian; the distal and proximal ends stand at an angle of about 45° to each other, and a strong deltoid process and ridge reach nearly to the middle of the

shaft. There are well-developed ect- and entepicondylar processes, but no entepicondylar foramen.

"The *radius* and *ulna* are well developed, but the articular ends do not show particular characters. The proximal and distal ends of both bones are rather widely expanded.

"*The foot:* There are six of the carpal elements preserved, seemingly in position. Between the distal ends of the bones is a small intermedium; at the distal end of each is a larger element in the position of the radiale and ulnare. The foot is somewhat turned so that the bone which lies at the end of the ulna may be either the ulnare or the centrale 2. Below the intermedium is a good-sized bone, the centrale 1. The radial digit is relatively long, and there is a stout metacarpal and three phalanges. It is not certain that the last phalanx is the terminal one, as the end of the digit is obscured by matrix. The other digits can not be exposed without injuring the specimen.

"*The vertebral column:* There are 10 anterior dorsal vertebræ preserved. The anterior six have the dermal plates preserved in position; the posterior four have lost them. The centra of the vertebræ can not be made out, but the neural arches are all free and there is little doubt that the general form is similar to that of *Trimerorhachis*. There are well-developed anterior and posterior zygapophyses, and from the base of the posterior one a narrow, winglike process extends downward and outward for the head of the rib. This process was attached solely to the neural arch. The neural spines are stout and strong with the apex expanded and rugose. The expansion of the apex of the spine in the posterior vertebræ is more nearly circular, but even here the lateral edges are more extended than the fore and aft edges. In the anterior vertebræ the sides become widely expanded, the projections extending outward and downward and meeting above in an angle, like an inverted V.

"Each of the anterior six vertebræ has the neural spine overlain by a single dermal plate in the form of an inverted V closely conforming to the apex of the spine and closely applied to it. The two sides of the plate meet in an angle of 120° to 130°, but there is no median ridge nor any trace of a suture to indicate that the plates were originally separate. The plates overlap each other from before backward, and did not extend laterally far beyond the extension of the neural spine; the upper surface is rugose with deep pittings. There is no trace of any lateral plates overlying the ribs, and the condition of the specimen is such that, if plates had existed, they would very likely have been preserved. The distal ends of the scapula and the cleithrum lie under the edges of the dermal plates, and it is likely that in life they nearly touched the edges of the neural spines.

"The *ribs* attached to the vertebræ have a slender, single head, but about a centimeter below the proximal end there is developed a thin, triangular process which extends backwards over the next following rib, and the point even reaches nearly to the second rib following. Below this process the ribs are flattened for some distance, but gradually assume the rounded form again. In more posterior ribs, perhaps posterior dorsals, the head of the rib is widely expanded and thin; it contracts rapidly, and about a centimeter below the head there is given off a process to the rear, as in the anterior ribs, but now the process is very slender and slants inward as well as backward. The rib is flattened proximally, more rounded distally.

"*Measurements.* MM

"Length of the humerus..... 54
Length of the radius..... 41
Length of the scapula (approximate)..... 60
Length of an anterior dorsal rib..... 45
Length of a posterior dorsal rib..... 35"

Revised description: This genus resembles *Cacops* Williston very closely, but differs in the ribs, which have strong posterior processes overlapping the succeeding rib. Williston (72) has suggested that this genus is a synonym of *Aspidosaurus*, but it is much closer to *Cacops*. There are dermal plates free from the neural spine, as in the *Dissorhophidæ*, while in the *Aspidosauridæ* the dermal armor is formed by expansion of the neural spines.

1–6. Mid-dorsal region, only, known.
7. Dorsal vertebræ with neural spines expanded but not wider than the vertebræ. Small dermal plates overlying the neural spines directly, and each overlapping the preceding plate, not wider than the vertebræ. No enlarged anterior plate.
8. Ribs double-headed, with a long, slender, posterior prolongation from a point near the upper end.
9. Cleithrum present, large, as in *Cacops*.

Genus CACOPS Williston.

Bull. Geol. Soc. Am., vol. 21, 1910, p. 253.

Type: A nearly complete specimen, No. 647 University of Chicago. From Wilbarger County, Texas.

Original description (in addition to the characters of the family *Dissorhophidæ* given by Williston, p. 51): "Dermal carapace but little wider than the vertebræ, narrowed in front and not fused into an anterior shield. Cleithrum thin and more expanded. Scapula less expanded below, the interclavicles and clavicles more slender."

Revised description:

1. Small, not exceeding 500 centimeters in length.
2. Skull not elongate, elevated, resembling in general proportions that of *Diadectes*. Orbits large, looking laterally and upward. Otic notch forming a closed fenestra.
3. Nares near the anterior end but more lateral in position than in *Dissorhophus*.
4. Parasphenoid, small, almost vestigial.
5. One tooth on each prevomer and palatine. Maxillary and mandibular teeth small and conical; 22 to 23 in the maxillary.
6. 21 presacral vertebræ, 2 sacrals, 6 pygals, and 15 to 16 chevron-bearing caudals.
7. Dorsal vertebræ with neural spines expanded, and wide anteroposteriorly. Dermal plates overlying and alternating with the neural spines. Narrow laterally, not greatly wider than the vertebræ; no enlarged anterior plate.
8. Ribs double-headed anteriorly, without posterior prolongation.
9. Cleithrum present; thin and more expanded.
10. Scapula less expanded below; the clavicles and interclavicles more slender.

Cacops aspidephorus Williston.

Bull. Geol. Soc. Am., vol. 21, 1901, p. 253.

Type: The same as that of the genus.

Original description: This is contained in the summary of the genus on page 62, and in the morphological description, page 119.

Revised description: Contained in that of the genus.

Family ASPIDOSAURIDÆ fam. nov.

1. Small.
2. Occipital condyles separate.
3. Otic notch present, small.
4. Unknown.
5. Unknown.
6. Apices of neural spines expanded into overlapping, rugose plates, forming an imperfect dorsal armor.
7. Unknown.
8. Unknown.
9. Unknown.
10. Unknown.
11. The two halves of the neural spine united.
12. Intercentra thick, constricting the notochordal space. Lateral processes for the head of the rib present.

This seems to be a well-established family characterized by the expansion of the neural spines and the development of lateral processes on the intercentra. The known specimens are fragmentary, but enough is known to suggest an animal resembling *Trimerorhachis* in the general form of the skull and probably of the body. The intercentra are much thicker than in *Trimerorhachis*, constricting the notochord more closely, and the lateral processes are unique. Facets in the same position are found on the intercentra of other *Amphibia* as *Alegeinosaurus*, and *Aspidosaurus chiton* seems to occupy an intermediate position between these and *Aspidosaurus glascocki*. The expansion of the spines was apparently for the same purpose as the more complicated dorsal armor in the *Dissorhophidæ;* specimens belonging in the two families are superficially very similar in this region.

Genus ASPIDOSAURUS Broili.

Aspidosaurus chiton Broili.

Paleontographica. Bd. LI, 1904, s. 40.

Type: A considerable portion of the skull and a portion of the vertebral column. Nos. 84 and 85, XV, 1901. Museum of the Alte Akademie, Munich. From Texas.

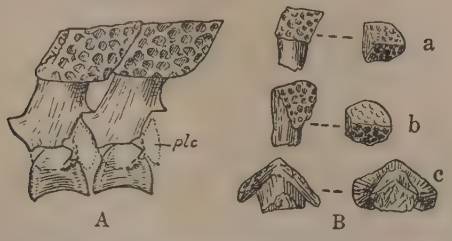


FIG. 13.—*A. chiton.* × ⅔. After Broili.

A. Two dorsal vertebræ from side. *plc*, pleurocentrum.

B. Apices of neural spines of three dorsal vertebræ. *a* and *b*, showing lateral and superior surfaces; *c*, showing posterior and interior surfaces.

Original description of the genus and species (translation of Broili's abstract of the description): "Skull triangular with a broadly rounded snout.

The large, round orbits mostly in the posterior half. The nares large, nearly round, widely separated from each other and located on the outer edges of the snout. Lyra absent. Otic slit present. The surface of the skull rough; the posterior prolongation of the supraoccipital without ornamentation. The small teeth of similar size, conical, slender, and closely set together.

"The lower surface of the skull shows trace of a thick plaster of chagrin teeth.

"Vertebræ rhachitomous. Neural spines expanded distally; with an arrangement like roofing tile, the surface roughly sculptured. The spines overlapping each other to form a sort of carapace."

Revised description of the genus:

1. Skull elongate triangular, with broadly rounded nose. Resembling *Trimerorhachis*.
2. Apices of neural spines expanded into overlapping rugose plates.
3. Intercentra without lateral processes for the head of the rib.

Revised description of the species:

1. Expanded processes of neural spines narrow: the two sides slanting upwards to meet in a narrow ridge.
2. The intercentra with distinct keel and the lateral processes small.

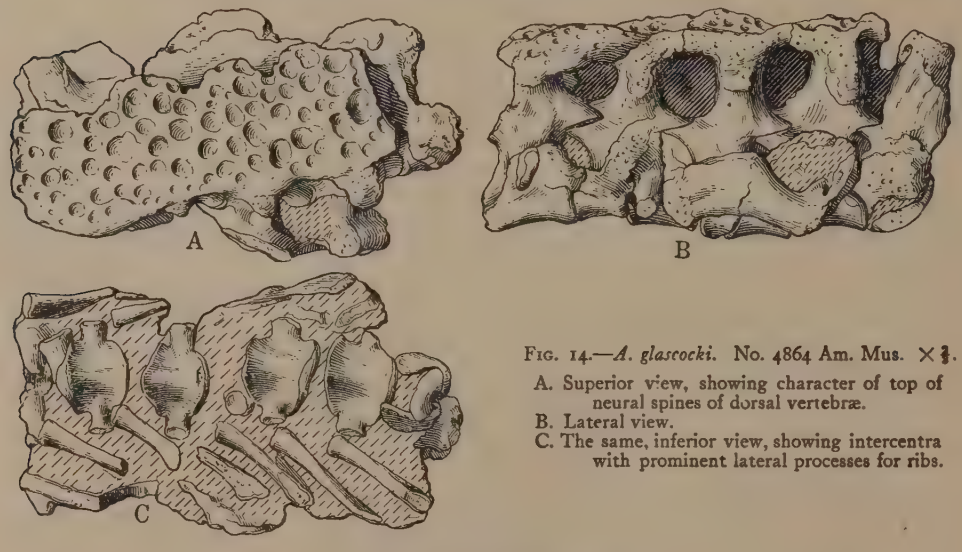


FIG. 14.—*A. glascocki*. No. 4864 Am. Mus. × ⅓.
A. Superior view, showing character of top of neural spines of dorsal vertebræ.
B. Lateral view.
C. The same, inferior view, showing intercentra with prominent lateral processes for ribs.

Aspidosaurus glascocki Case.

Bull. Am. Mus. Nat. Hist., vol. XXVIII, 1901, p. 179.

Type: A portion of the vertebral column with fragments of the skull. No. 4864 Am. Mus. Nat. Hist. From Texas.

Original description: "The new species, *A. glascocki*, differs from *A. chiton* Broili, in having the expanded apices of the neural spines much larger and marked with a coarser sculpture. The apices of the spines touch but do not overlap. The intercentra have prominent processes on the sides for the heads of the ribs. In *A. chiton* there are facets, a little more prominent than in *Eryops* and *Trimerorhachis*, while in *A. glascocki* they are extended

far out from the sides of the intercentrum for two or three millimeters. The skull resembles that of *Trimerorhachis*, so far as it is preserved. The animal was about 30 centimeters long."

Revised description:

1. Expanded neural spines more nearly flat; the apices of adjacent spines closely united, so that the connection is indistinct.
2. Intercentra with low median keel, the lateral processes prominent.

Aspidosaurus apicalis Cope.

Cope, *Zatrachys apicalis*, Am. Nat., vol. 15, 1881, p. 1020; Am. Nat., vol. 18, 1884, p. 36.

Type: The apices of several neural spines. No. 4785 Am. Mus. Nat. Hist. Cope Coll. From New Mexico.

Original description: "The summits of the neural spines are expanded, and the superior faces of the expansions are tubercular and have a median prominence. The expansions are sometimes large, resembling the dermal bones of crocodiles, and in that case the median prominence is a keel. On the smaller expansions the latter is a mere apex. There are narrow flat bones which I suppose to be neural spines and which are ornamented with inosculating ridges. A capitular head of a diapophysis is compressed. Intercentra well ossified, those preserved without lateral notch. Inferior surface with crowded small fossæ, giving a delicate reticulate relief. Length of an intercentrum, .013; width of do., .014; width of the summit of a neural spine, .020; length of do., 014; width of a second do., .025; length of do., .015; width of a third (two unite), .034; length of do., .039. The reference of this species is provisional only. It is much larger than the *Z. serratus*."

In the second paper Cope added:

"In the typical species, *Z. serratus*, the rugosities project in the form of teeth along the external alveolar border. Individuals with sculptured, neural spines and dermal bones are referred here. The intercentra are much like those of *Eryops* and *Acheloma*."

Revised description: Cope's reference of this species was at first uncertain; but when he decided to place in the genus all forms with expanded spines and skulls with serrate edges, he placed it in the genus definitely.

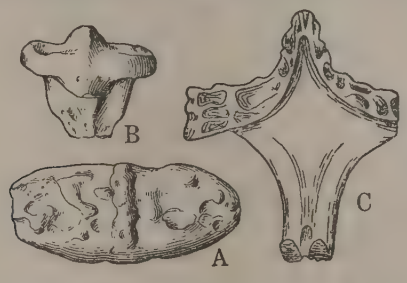


FIG. 15.

A. *A.* (*Zatrachys*) *apicalis*. No. 4785 Am. Mus. × 1. Top view of spine.
B. Lateral view of same spine
C. *A. crucifer*. No. 171 Univ. of Chicago. × 1. Posterior view of neural spine of a dorsal vertebra.

As has been shown, the skull of *Aspidosaurus* in no wise resembles that of *Zatrachys*. The specimen is referred to *Aspidosaurus* provisionally; the wide geographic separation makes it very possible that when more is known of the creature, it will be found to be generically distinct at least.

1. Only the apices of the spine known. Flat, oval in outline, with a peg-like apex. Overlapping slightly.

Aspidosaurus crucifer Case.

Zatrachys crucifer, Case, Journ. Geol., vol. xi, 1903, p. 399.

Type: A single neural spine. No. 171 University of Chicago. From Texas.

Original description: As shown in the accompanying figure, "the spine has a cruciform shape with a sharp upper portion and short lateral processes. The posterior zygapophyses are preserved and are relatively small. The upper faces of the lateral processes and the apex of the spine are pitted by a deeply marked rugosity so that the whole upper surface of the spine is excavated by deep pits of a size and depth seen before only in the larger amphibians, *Eryops* and *Cricotus*. The lower surfaces of the lateral processes and the sides of the base of the spine are smooth. The anterior and posterior edges of the apex are free from the deep pits and are marked by a narrow space of striations showing that the spine was overlapped by the edges of some other element; it is evident from the shape of the spine that this could not have been the edges of the adjacent spine, but must have been an extra element intercalated between the spines, probably one of the dermal ossifications such as occur along the spines of *Pareiasaurus*. The nearest approach to this condition is found in the rugose expanded apices (of the spines) of *Zatrachys apicalis* Cope, and so I have referred this specimen to that genus, until further information may be obtained. The fragment is .054 m. in height and .058 m. across the lateral processes."

Revised description:

1. Only a single neural spine known. The apex with a prominent median spine and narrow lateral process. Adjacent process touching, but overlapping very slightly.

Family TREMATOPSIDÆ Williston.

Bull. Geol. Soc. Am., vol. 21, 1910, p. 278.

Original description: "A median foramen back of premaxillæ; large antorbital vacuities. Otic notch wholly inclosed by bone, the opening small and extending far forward. Palate with two pairs of large teeth back of the nares and a single one on each vomer. No parasphenoid. Ribs short, the anterior ones expanded distally. Twenty-two or twenty-three presacral vertebræ; a single sacral; tail short. No dermal armor or carapace. Cleithrum unknown. Clavicles and interclavicle small, without dermal pittings. Humerus with ectepicondylar process."

Revised description:

1. Small, about 500 cm. long, head disproportionately large.
2. Occipital condyles separate.
3. Otic notch small, completely closed, forming a fenestra.
4. Parasphenoid vestigial, or absent.
5. One functional sacral rib.
6. No armor on back.
7. Clavicles and interclavicles without external sculpture.
8. Cleithrum unknown, probably present.
9. Humerus with ectepicondylar process as in *Eryops*.
10. Femur with prominent ridge on posterior face resembling *Eryops*.
11. The two halves of the neural spine united.
12. Intercentra thick, constricting the notochordal space. No processes on the sides of the intercentra for the ribs.

Genus TREMATOPS Williston.

Trematops milleri Williston.

Journ. Geol., vol. XVII, 1909, pp. 636–658.

Type: A nearly complete skeleton, No. 640 University of Chicago. From Wilbarger County, Texas.

Original description of the genus and species (abstracted from Williston's description): Skull triangular, the width posteriorly, but slightly less than the length of the middle line. Surface deeply and coarsely pitted but with no trace of lyra. Facial region markedly constricted just anterior to the orbits; posterior to the orbits the skull is broad and flat. A median, unpaired opening on the anterior portion of the snout opening into a palatine vacuity. Two large antorbital openings, perhaps the nares, with septomaxillary bones. Temporal fenestræ present. Parietal foramen small. Sutures mostly indistinguishable, such as are made out shown in fig. 3, plate 14. Occipital condyles paired; parasphenoid absent (?). A large tooth just anterior to the internal nares, probably on the vomers. Four large teeth on each palatine, arranged in pairs. Twenty-five or twenty-six teeth in each maxillary and mandible. Twenty-three to twenty-five presacral vertebræ. Two sacrals. Vertebræ rhachitomus. Ribs expanded at the extremities, little curved. Scapulacoracoid similar to that of *Eryops;* cleithrum absent (?); clavicle and interclavicle small, without sculpture on the outer surfaces. Humerus similar to that of *Eryops*. Pelvis resembling that of *Eryops* in general. "The femur resembles in miniature that of *Eryops*." Twelve tarsal bones, three in the proximal row, four in the middle and five in the distal row. The digits short and heavy with clawless, terminal phalanges. Phalangeal formula, as preserved, 1, 2, 3, 4, 2; possible formula due to the addition of a small ossicle to the first, second, and fifth digits, 2, 3, 3, 4, 3.

Revised description of the genus and species:

1. Skull triangular, abruptly narrower anterior to orbits.
2. Orbits in middle of skull looking upward.
3. Nares united with elongate antorbital openings.
4. A single, medial opening at extremity of nose.
5. Otic notches in the form of fenestræ.
6. Maxillary and mandibular teeth subequal, conical. A single tusk on the prevomer and two pairs of tusks posteriorly, probably on the palatine and maxillary.
7. Humerus with an ectepicondylar process and short entepicondylar process. Condyles well developed.
8. Femur with a thin ridge on the posterior face.
9. Twelve tarsal bones.
10. Phalangeal formula of hind foot 2, 3, 3, 4, 3. Terminal phalanges without claws.

Order URODELA (?)

Family LYSOROPHIDÆ Williston.

Williston, *Lysorophidæ*, Biological Bull., vol. xv, 1908, p. 237.
Broili, *Paterosauridæ*, Paleontographica, Bd. li, 1904, s. 99.
Broili, *Paterosauridæ*, Anat. Anzeig., Bd. xxv, 1904, s. 585.

Original description: Broili founded this family on "the character of the vertebræ, the lack of intercentra, and the presence of jugular plates."

Williston showed that while the form was properly placed in a new family, the name was given in opposition to the accepted rules of nomenclature and that it should properly be named *Lysorophidæ*.

Revised description: The family is regarded as an amphibian in opposition to Broili's contention that it is a reptile, for reasons given in the morphological discussion (p. 141).

1. Small, snake-like, limbless.
2. Skull triangular, without temporal fenestræ or parietal foramen.
3. Anterior nares on outer edge of skull, nearly terminal.
4. Orbit lateral, without lower borders.
5. Quadrate inclined forward, bringing articular surface beneath the posterior edge of the orbit.
6. Teeth small and conical. None enlarged.
7. Lower jaw two-thirds of the length of the skull.
8. Limbs and girdles absent.
9. Neural arch free from centrum and divided into lateral halves.

Genus LYSOROPHUS Cope.

Lysorophus tricarinatus Cope.

Cope, Proc. Am. Phil. Soc., vol. xvii, 1877, p. 187.
Case, Journ. Geol., vol. viii, 1901, p. 714; Journ. Geol., vol. x, 1902, p. 256; Bull. Am. Mus. Nat. Hist., vol. xxiv, 1908, p. 531.
Broili, Paleontographica, Bd. li, 1904, s. 94; Anat. Anzeig., Bd. xxv, 1904, s. 585; Anat. Anzeig., Bd. xxxiii, 1908, s. 290.
Williston, Biol. Bull., vol. xv, 1908, p. 229.

Type: A few vertebræ, No. 6526 University of Chicago, badly broken.

Paratypes: Nos. 6527, 6528 University of Chicago. Vermilion County, Illinois.

Original description: "Vertebræ amphicœlian, perforated by the foramen chordæ dorsalis. Neural arch freely articulated to the centrum. Floor of neural canal deeply excavated. No processes or costal articulations on the centrum, which is excavated by longitudinal fossæ. Centrum not shortened.

"*Specific characters:* Two centra and a portion of a third represent this species. The former are a little longer than wide and a little depressed. The facet for the neural arch is an elongate plane truncating the border of the fossa of the neural canal on each side, for one-half to three-fifths the length of the centrum. Two deep longitudinal fossæ extend on each side of a median rib of the inferior face; and they are separated above by a narrower rib from another longitudinal fossa which is below the base of the neural arch.

"*Measurements.*

"Diameter of centrum:	M
Longitudinal	0.0055
Vertical	.0038
Transverse	.0040
Length of facet for neurapophysis	.0035
Width of neural canal	.0020"

Revised description: Contained in the revised description of the family.

INCERTAE SEDIS.

Suborder GYMNARTHRIA Case.

Bull. Am. Mus. Nat. Hist., vol. XXVIII, 1901, p. 177.

Known from the skull only.

1. Skull completely overroofed; no temporal foramina, but lower edge of temporal region cut away as in some of the turtles. Lyra (*Cardiocephalus*) and parietal foramen (*Gymnarthrus*) present.
2. Quadrate free, not covered by the prosquamosal.
3. Quadratojugal absent and the prosquamosal reduced to small size or absent.
4. Basisphenoid and parasphenoid forming a large plate on the lower surface of the skull.
5. Lower jaw as long as the skull.

Family GYMNARTHRIDÆ Case.

Characters given in the suborder.

Gymnarthrus willoughbyi Case.

Case, Bull. Am. Mus. Nat. Hist., vol. XXVIII, Art. XIX, 1910, p. 177.
Broom, Bull. Am. Mus. Nat. Hist., vol. XXVIII, Art. XX, 1910, p. 219.

Type: A small skull. No. 4892 Am. Mus. Nat. Hist. From Wilbarger County, Texas.

Homotype: A second skull. No. 4763 Am. Mus. Nat. Hist. Cope Coll. Locality unknown.

The teeth are blunt cones with no indication of anterior and posterior cutting edges. The three teeth anterior to the last slightly larger than the others, but all the teeth decreasing regularly in size to the anterior end; this includes the premaxillary teeth, so that there are no enlarged incisors. Nine teeth in the maxillary and three or four in the premaxillary. A large parietal foramen. No lyra present.

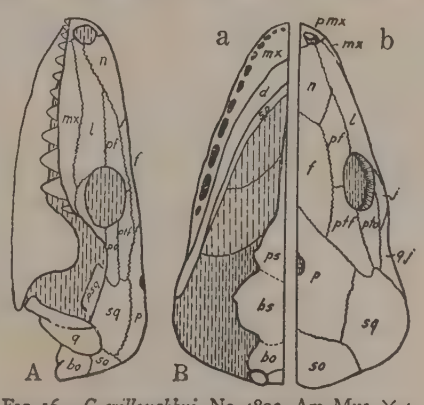


FIG. 16.—*G. willoughbyi*. No. 4892. Am. Mus. × 4.
A. Lateral view of skull.
B. The same. *a*, lower surface; *b*, upper surface.

This animal was originally regarded as a reptile, but a comparison with the type of *Cardiocephalus sternbergi* Broili shows that the two forms are closely related if not identical. *Cardiocephalus* has distinct lyra and the parietal foramen is either absent or very small. For these reasons *Gymnarthrus* is retained as a separate genus, but transferred provisionally to the *Amphibia*. Broom (10) regards it as probably amphibian.

Genus CARDIOCEPHALUS Broili.

Cardiocephalus sternbergi Broili.

Paleontographica, Bd. LI, 1904, s. 45.

Type: Two small skulls, one with a few vertebræ, No. 147, XV, 1901, Museum of the Alte Akademie, Munich. From Texas.

Original description of the genus and species (abstracted from Broili): Outline of the skull somewhat heart-shaped. The proportionately rather large orbits in the anterior half of the skull on the gently sloping side of the face. Nares rather large, widely separated, on the anterior end of the nose. Skull smooth and shining. Suture not definite; the probable position of the bones as indicated in the figure. Lyra present. Teeth proportionately large and compressed, becoming smaller anteriorly, with sharp fore and aft cutting edges. Number of teeth observed, ten. Lower jaw as long as skull.

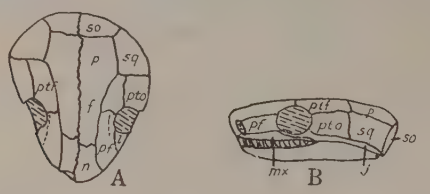


FIG. 17.—*C. sternbergi.* × ⅔. After Broili.

A. Upper view of skull.
B. Lateral view of skull. *n*, nasal; *pf*, prefrontal; *l*, lachrymal; *f*, frontal; *ptf*, postfrontal; *pto*, postorbital; *p*, parietal; *sq*, squamosal; *so*, supraoccipital plate; *mx*, maxillary; *j*, jugal + prosquamosal (?)

Revised description: This genus is very close to *Gymnarthrus*, as noted above; for further description see morphological discussion, page 144.

Genus CROSSOTELOS Case.

Crossotelos annulatus Case.

Case, Second Ann. Rpt. Dept. Geol. and Nat. Hist., Territory of Oklahoma, 1903–4, p. 65.
Williston, Bull. Geol. Soc. Am., vol. 21, 1910, p. 271.

Type: A series of vertebræ. No. 4343 University of Michigan. From Oklahoma.

Original description: "A very interesting series of vertebræ, which occur quite commonly in the collection, indicate the presence of a form that is especially noteworthy from the resemblance which it bears to forms from other localities. Most notable among its peculiarities is the fact that the upper portion of the neural spine and the extremity of the hæmal spine in the caudals are marked by slender striations such as distinguish the genera *Keraterpeton* and *Urocordylus*, from the Permian of Ireland and Bohemia, and the genera *Ptyonius* and *Oestocephalus* from the Carboniferous of Linton, Ohio. The vertebræ show the same character of close articulation of the vertebræ that is evidently present in the genera mentioned. In the dorsals there is not a very distinct zygosphene and zygantrum articulation, but there is a strong interlocking of the sides of the neural arch by prolonged interdigitations and this character is carried on to the neural arch so that even to the summit the arches interlock, almost by craniate suture. In the caudals the interlocking digitations are absent, but there are present well-defined zygosphene and zygantrum articulations such as are figured by Frisch as present in *Urocordylus* and described by Cope in *Oestocephalus remex*.

"In the dorsals the top of the neural spine is rather broad and the markings on the sides are very sharp, but neither so deep nor so long on the side of the spine as in the genera with which it is compared. On the sides of the

dorsals a strong ridge connects the anterior and posterior zygapophyses; the parapophysis extends from another very prominent ridge just beneath this so that there are two parallel ridges on the sides of the centrum in the mid-dorsal series which disappear toward the caudal end. This is a very prominent character and forms one of the most pronounced features of the genus. In the caudal series the hæmal arches are well developed, reaching nearly or quite the length of the neural arches. The markings on the sides of the arches, both upper and lower, are evident but much fainter than in the dorsal series and much fainter than in the genera with which this one has been compared. The belly was abundantly covered with abdominal scales in the form of slender rods of bone, resembling in this feature again the forms

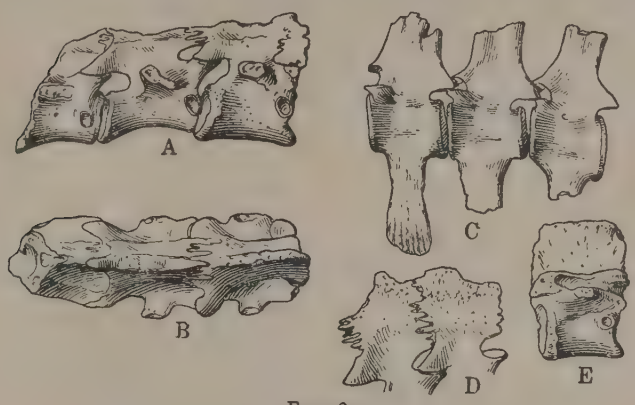


FIG. 18.

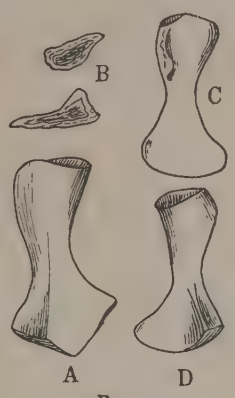


FIG. 19.

FIG. 18.—*Crossotelos annulatus*. No. 3040 Univ. of Michigan. × ⅔.
A. Three dorsal vertebræ, lateral view.
B. The same vertebræ, superior view.
C. Three caudal vertebræ.
D. The spines of two dorsal vertebræ, showing the close interlocking.
E. A single dorsal or anterior caudal vertebra, showing the ridge at the base of the neural arch.

FIG. 19.—*Crossotelos annulatus*. Specimens in the University of Chicago.
A. Right humerus, posterior view.
B. Proximal and distal ends of the left humerus of another specimen.
C. The same humerus shown in B, from the posterior side.
D. The same, anterior view.

mentioned above. Another point in the structure of these vertebræ is the absence of sculpture and the constant presence in both the dorsal and caudal series of a foramen on the side of the vertebræ; in the dorsals it occurs just posterior to and below the parapophysis and in the caudals just below the posterior to the anterior zygapophysis. In all the vertebræ the ends are deeply cupped and the arches are coossified with the centrum.

"*Measurements.*	M
"Length of one dorsal	0.0135
Length of a second dorsal	.012
Height of the neural spine from the bottom of centrum	.0205
Length of one caudal	.0095
Length of the chevron from the bottom of centrum	.014
Length of a second caudal	.0095
Height of the neural arch above bottom of centrum	.0165"

Revised description: This genus is known from the vertebræ and humeri only. The foramen mentioned as occurring below the parapophysis is prob-

ably the deeply cupped facet for the capitulum of a double-headed rib. A sharp ridge on the sides of the vertebræ, just at the base of the neural arch, is very similar to the same structure figured by Fritsch on the sides of the vertebræ of *Keraterpeton* and *Urycordylus* from Bohemia, but an examination of the specimens preserved in the museum at Prague did not reveal this feature, probably because of the very poor preservation of the specimens.

Williston has figured the humerus of *Crossotelos* and gives the following description:

"It is a simple bone, moderately expanded at the extremities, with a rather deep concavity longitudinally behind, and with but a small lateral rugosity. All the specimens found show an incomplete chondral ossification. The form was doubtless more or less aquatic."

Williston also notes the presence of fine, abdominal ribs.

B. EMBOLOMERUS Division.

Family CRICOTIDÆ Cope.

Am. Nat., vol. XVIII, 1884, p. 38; Am. Nat., vol. XXVIII, 1889, p. 861; Syllabus of Lectures, 1898, p. 46.

Original description: "In the family Cricotidæ the chorda dorsalis is persistent and large. The vertebral centra and intercentra are perforated so as to resemble some kinds of discoidal beads. They form a characteristic feature among the Permian fossils. The abdomen is protected by scales arranged in chevrons. There is a parietal foramen, and the supratemporal bone has a free external border like the squamosal of the crocodile."

Revised description:

1. Skull elongate, like *Archegosaurus* in form.
2. Nares not terminal, near outer edge of skull.
3. Orbits near middle of skull looking upward and outward.
4. Intercentra complete perforated disks forming, with the similarly developed pleurocentra, embolomerous vertebræ.
5. Two (?) sacral vertebræ, anterior one with a large rib.
6. Caudal vertebræ numerous. Chevrons coossified with intercentra.
7. Ilium reptilian, with strong projection to the rear.
8. A close abdominal armor of imbricate scales, arranged in a chevron pattern.

Genus CRICOTUS Cope.

Proc. Phil. Acad. Sc., 1875, p. 405; Proc. Am. Phil. Soc., vol. XXII, 1884, p. 28; Am. Nat., vol. XVIII, 1884, p. 39.

Type: Some caudal vertebræ and other bones. Nos. 6517, 6519, 6520 University of Chicago. From near Danville, Illinois.

Original description: "The caudal vertebra best preserved is stout, discoidal in form, and deeper than wide. It resembles in form that of an herbivorous dinosaurian, but differs otherwise. The articular faces are deeply concave, the posterior most strongly so; and the middle is occupied by a large foramen, whose diameter is about equal to that of the centrum on each side of it. The lateral borders of the posterior articular face are expanded backwards, and articulate with a bevel of the corresponding edge of the

anterior articular extremity. In this way the vertebra combines the mechanical relations of the biconcave with the opisthocœlian structures. The neural arches are narrow, and directed backwards; their bases are firmly coossified with the centrum, no zygapophyses appear on the portion of the neurapophyses preserved, and it is probable that they were weak if existing. On the inferior surface of the centrum two shallow pits occupy considerable space, and indicate the existence of large, free, chevron bones. No transverse processes. In one vertebra the floor of the neural arch is deeply excavated; in the other it is plane and marked with a median groove."

The remainder of the description is given up to the limb bones, which were conjectured by Cope to belong to *Cricotus;* the association is more than doubtful and it seems of no value to continue their description with that of the type vertebræ. In the description, Cope had the intercentrum (which he took for a centrum) inverted, and allowance must be made for this. He recognized this error himself, and in his drawings of a slightly later date (which were never published) he corrected it.

In 1884 Cope added considerably to his original description:

"Accession of additional material enables me to add several points to the knowledge of the osteology of this genus, and to distinguish satisfactorily three species. I have much pleasure in obtaining these additional facts, since everything relating to this curious genus is of interest.

"In the first place, the neural arches are not coossified to the centra, but are readily separated from them. Their basis of attachment forms, on each side of the median neural canal, an oblique triangular surface looking forwards and upwards, with the apex above and behind. The ease with which the neural arches separate accounts for the rarity of their occurrence on separate centra. They support the diapophyses at their lower border. Second, that the sacrum consists only of a centrum and an intercentrum, both of which take part in furnishing a concave facet for the attachment of the pelvis. Third, some of the ribs are two-headed, and their capitular articulation is with the posterior edge of the intercentrum. Fourth, there is a hyposphenal articulation, as in the genera of Jurassic Saurians, Camarasaurus, Amphicœlias, etc., and in the Permian genus *Empedias*, among the Theromorpha. The hypantrum has, however, this peculiarity: that its sides are produced forwards into a process on each side below the prezygapophyses, each of which is subconical in form, but with the interior face excavated to receive the hyposphen, so that the section of the process is crescentic. These processes I have never previously observed. I call them hypantrapophyses. I find them in the *Cricotus hypantricus.* The neural arches of the other species are either lost or in such close juxtaposition that I can not see them."

In the "American Naturalist," in his account of the "Batrachia of the Permian Period of North America," Cope gives the following account of the genus:

"In this genus the teeth are rather large, and are of subequal size in the external rows. The tail is long, and was apparently useful as a natatory organ. The terminal phalanges are obtuse as in salamanders, and without claws. The pelvis has the character of that of the Eryopidæ, but is less massive anteriorly. The lower jaw has no posterior projecting angle. There are mucous grooves on the skull. The abdominal scales are oblong and in close contact with each other."

Revised description: This is contained in that of the family.

Cricotus hypantricus Cope.

Proc. Am. Phil. Soc., vol. xxvii, 1884, p. 30; Trans. Am. Phil. Soc., vol. xvi, 1888, p. 253, plate 1, figs. 2–6.

Type: Several dorsal vertebræ. No. 4552 Am. Mus. Nat. Hist. Cope Coll. From Texas.

Original description: "This Embolomere is probably represented by two individuals, which are of larger size than any species which have hitherto come under my notice, one of them much larger. It is only the smaller specimen which is accompanied by the astragalus. Both of them display the hypantropophyses already mentioned in remarks on the genus under the head of *C. crassidiscus*. (See the original description of the genus.)

"As already pointed out in the key of species, the dorsal intercentra in *C. hypantricus* (see description of *C. crassidiscus*) are stout and not narrow above, but the thickness increases rather than diminishes upwards. They thus differ from the corresponding intercentra in the *C. heteroclitus*. In many of the dorsal intercentra the dense external layer which covers the inferior face continues upwards to an apex, the articular surfaces of the two ends meeting so as to exclude the former. This is also the case in the *C. crassidiscus*. The centra have the abbreviated form characteristic of the genus, and the foramen chordæ dorsalis is present, but is smaller than the *C. heteroclitus*.

"The supposed astragalus is oblong; proximal border longer than the distal, which is separated by an obtuse angle from the ectad; distal entad not reaching superior surface of bone, long, extending inwards below the revolute proximal part of the entad face, from which it is separated by a narrow oblique groove. Proximal and distal entad separated by notches of the two faces; a ridge the length of the bone below.

"*Measurements.*

"Diameters of centrum of individual with astragalus:	M
Anteroposterior	0.015
Transverse	.028
Diameters of astragalus:	
Anteroposterior	.038
Transverse	.029
Diameters of centrum of larger individual:	
Anteroposterior	.018
Transverse	.038
Diameters of adjacent intercentrum of same:	
Anteroposterior	.013
Transverse	.038"

Revised description: The hyposphene and hypantrum described by Cope are very low down so that the projections appear from the sides of the neural canal and are apparently received into the neural canal of the adjacent vertebra. The neural arch is closely attached to the centrum and in some the suture can no longer be made. The transverse process extends directly out from the neural arch. In some in which the neural arches are lost the side of the centrum is continued up nearly to the edge of the neural canal; in others the facet for the neural arch extends at least one-third of the way down the side. In some vertebræ there is a small facet on the centrum near the lower end, which meets a corresponding one on the intercentrum; it would seem that this facet should be for the capitulum of the rib, but, so far as

noticed, the ribs of *Cricotus* are single-headed. The centrum and intercentrum take nearly equal part in the support of the large head of the sacral rib.

For a comparison with the other species see the original description of *C. crassidiscus*.

Cricotus gibsonii Cope.

Cope, Proc. Am. Phil. Soc., vol. XVII, 1877, p. 185; Am. Nat., vol. XVIII, 1884, p. 39.
Case, Journ. Geol., vol. VIII, 1900, p. 709.

Type: Several vertebræ of similar form, Nos. 6521 and 6522 University of Chicago. From near Danville, Illinois.

Original description: "The vertebra which is best preserved and which may be regarded as typical is probably from the caudal series, and is thus well contrasted with the corresponding typical vertebræ of the longer known species.

"On this vertebra there is no trace of a diapophysis, and the neurapophysis rises from the external side of the superior face. The wall of the neural canal is not preserved, but the inference is that the diameter of the latter is large. This fact and the absence of definite chevron articulations leads me to doubt the caudal position of the vertebra; but the usual marks of the dorsal and cervical vertebræ are totally wanting from it. As in *C. heteroclitus*, the *foramen chordæ dorsalis* is large, its diameter being one-third of the total. The articular faces descend steeply into it, that of one extremity more so than the other. The rim of the latter face is beveled outwards, the plane thus produced appearing on the inferior face something like the united faces of the chevron bones.

"The centrum is a little deeper than wide, and the inferior face is truncate so as to give a subquadrate outline. The inferior plane is concave, the concavity being divided by a longitudinal rib. The sides are somewhat concave, with a longitudinal rib at the middle. Diameters of centrum: vertical .010 m.; transverse .009; longitudinal .008. Width of the inferior plane .005; width above, including neurapophyses .008.

"As compared with *C. heteroclitus*, this species differs in the presence of parallel ridges inclosing a median fossa on the inferior side of the centrum. The small size may be here considered, but it is uncertain whether the two animals represented by the vertebræ are full grown."

Revised description: It is doubtful whether this species could be distinguished from the others or not. It is very possible that the vertebræ are from some portion of the column not represented in other specimens. Cope does not mention it in the analysis of species given in 1884 (38), and apparently regarded it as included in the description of *C. heteroclitus*.

Cricotus heteroclitus Cope.

Cope, *C. heteroclitus*, Proc. Phil. Acad. Nat. Sc., 1875, p. 405.
C. discophorous, Proc. Am. Phil. Soc., vol. XVII, 1877, p. 186.
C. heteroclitus, Proc. Am. Phil. Soc., vol. XVII, 1878, p. 523.
Case, *C. heteroclitus*, Journ. Geol., vol. VIII, 1900, p. 708.

Type: The same as the genus. No. 6518 University of Chicago, Type of *C. discophorous*.

Original description: "The surface of the sides of the centrum (intercentrum) is marked with a few coarse shallow longitudinal grooves, which run into shallow reticulations of weak raised lines. The neurapophysis is sharp-edged in front, and with some ridges externally at the base.

"The edge of the posterior articular face is excavated opposite to the chevron facets. The latter are large, are separated by a flat surface, and are bordered externally by a raised edge from the polished dense layer of the lateral face.

"*Measurements.*

"Diameter of centrum (intercentrum):	M
Vertical	0.021
Transverse	.019
Longitudinal	.011
Width of neural canal	.006
Width of neurapophysis	.004"

In the second paper cited, Cope described a dorsal intercentrum of this species as a distinct species, *C. discophorous;* he corrected this in the third paper. The description is as follows:

"The centrum (intercentrum) is diskiform, with very short antero-posterior diameter, which is, however, greater at one part of the surface than at the opposite point. The *foramen chordæ dorsalis* occupies about one-fifth of the transverse diameter, which is subequal in all directions. The articular faces of the centrum are slightly concave. The margin of that of one side is beveled for the superior two-thirds of the circumference, the bevel running out below by turning into the articular face. The latero-inferior border of the latter turns out into an obtuse angle at this point. The superior part of the bevel runs into the lateral face of the centrum. The attachment of the neural arch is obscure or wanting in the specimen, and the same is true of any facet for chevron bones.

"*Measurements.*

"Diameter of articular face:	M
Vertical	0.025
Transverse	.025
Length of centrum below	.009
Length of centrum above	.007

"Another vertebra of nearly the same character, and one-half smaller in size, presents a greater difference between the long diameters of the upper and lower sides. The superior diameter is only one-half the inferior, and the *foramen chordæ dorsalis* much nearer the superior than the inferior margin. Its diameter is one-fourth the vertical and one-third the transverse diameter."

In the third paper Cope gave an extended account of the species, but the specimens on which it was founded were subsequently, 1884 (38), made the type of a new species, *C. crassidiscus.*

Revised description: See *C. crassidiscus.*

Cricotus crassidiscus Cope.

Proc. Am. Phil. Soc., vol. XXII, 1884, p. 28; Proc. Am. Phil. Soc., vol. XVII, 1878, p. 522 (*C. heteroclitus partim*); Am. Nat., vol. XVIII, 1884, p. 39 (*C. heteroclitus partim*).

Type: Two imperfect skeletons, Nos. 4550, 4550*a* Am. Mus. Nat. Hist. Cope Coll. From Texas.

Original description:

"I. Dorsal intercentra much narrowed or pinched above. Hypantrum unknown ..... *C. heteroclitus*

II. Dorsal intercentra equally robust above as below, or more so. Hypantrum unknown ..... *C. crassidiscus*

Hypantrum with acute lateral processes ..... *C. hypantricus*"

The measurements of the *C. crassidiscus* are as follows:

"*Measurements.*

	M
"Diameters of dorsal centrum behind:	
Vertical	0.025
Transverse	.025
Length of do.:	
Middle line below	.013
At base of neural arch	.013
Base of neural arch:	
Width	.010
Length	.009
Diameters of a dorsal intercentrum:	
Vertical	.025
Transverse	.025
Length of do.:	
Middle line below	.009
Middle line above	.0095
Diameters of coracoid, transverse length	.027
Diameters of coracoid, width:	
Glenoid face	.029
Internal face	.010"

See also quotation from same paper in original description of the genus.

In the second paper cited, Cope described as *C. heteroclitus* a specimen with the skull, which he later made the type of this species. It was regarded by him as a single specimen, but turns out to contain parts of two animals:

"Specimens of a number of individuals probably referable to the above species, exhibit many of its characters. These are very remarkable, and indicate another type of vertebral column heretofore unknown.

"The intercentra are more largely developed than in any other genus, having the form and proportions of the centra in the caudal region, and being but little smaller in other portions of the column. In the prepelvic region, the true centra only bear neural arches, which are articulated, and bear short diapophyses at their base. In the caudal region they share the neural arches with the intercentra, while the latter bear the continuous chevron bones exclusively. The neural spines are well developed, and not prolonged, in both regions. The ribs are robust, and the abdomen is protected beneath by a series of long, narrow and flat scales, which form imbricated chevrons directed forwards at the middle line.

"The phalanges are short and wide, with but slightly condyloid articulations. The distal one is very short, and terminates in a narrowed obtuse projection, somewhat like those of man, but shorter.

"A cranium which accompanied the portions of the trunk above described, may belong to the same species. It is that of a Labyrinthodont in some degree allied to *Trematosaurus*. Its form is elongate and the orbits are behind the middle. The mandibles do not exhibit prominent angles, and the epiotic angles are not distinguished by a notch from the posterior border of the os-quadratum. The epiotic bones and two supraoccipitals form the posterior boundary of the table of the cranium, anterior to which the usual parietals and pterotics extend to the frontals and post-frontals. Below the latter is the post-orbital, which is bounded behind by the squamosal (supra-squamosal, Owen, Paleontology, p. 176). The quadratojugal is possibly distinct from the large malar. There is a lyra of two grooves, which are widely separated on the anterior part of the muzzle, and which converge in front of the orbits, which they barely reach. Another groove

occupies the inferior margin of the dentary bone. There is a deep auricular fossa beneath the epiotic and posterior part of the pteriotic bones. There is but one series of teeth on each maxillary and dentary bone exposed by the present condition of the specimen. The teeth are subequal, gradually increasing in size anteriorly, where their long diameters are transverse to the axis of the dentary bone. The surface of the cranial bones is not strongly sculptured. Posteriorly it is rather closely and anteriorly it is sparsely punctate. The sculpture of the lower jaw is similar, except that it is smoother posteriorly."

Revised description: The species of *Cricotus* are very uncertain because of lack of material. The analysis given in the original description above is probably as good as any that can be given. *C. hypantricus* is a good species; it is doubtful whether *C. heteroclitus* and *C. crassidiscus* are distinct.

Genus CRICOTILLUS Case.

Cricotillus brachydens Case.

Second Ann. Rpt. Dept. Geol. and Nat. Hist. Territory of Oklahoma, 1902–3, p. 65.

Type: The fragment of a rostrum. No. 349 University of Kansas. From northwest of Orlando, Oklahoma.

Original description: "A fragment of a rostrum indicates the presence of a new genus and species of amphibian. The fragment is from the middle portion of the maxillaries, between which appear in the posterior half the anterior part of the nasals, and on the lower surface the vomers. The upper surface of the maxillaries is sculptured by low longitudinal ridges, especially upon the upper surface. The maxillary is triangular in section, the upper surface is convex, and the inner or vomerine side and the dentigerous surface is flat or slightly concave. The inner or lower surfaces meet in a very sharp ridge. The vomers are very narrow, but of considerable vertical extent, and lie closely apposed to the vomerine sides of the maxillary; they project as sharp ridges on the lower side of the skull. The teeth are represented by the roots alone; their chief characteristic is the relative breadth of the roots, approaching in this respect the *Diadectidæ*. They are from two to three times as wide as long. The tooth line is somewhat concave inwardly, following the curve of the maxillary bone, and the teeth are anchylosed to the dentigerous surfaces.

"*Measurements.*

	M
"Total length of the fragment (about half the length of the head, probably)	0.030
Width of the anterior end	.015
Width of the posterior end	.021"

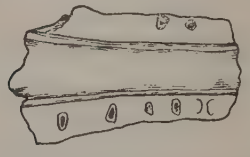


FIG. 20.—*Cricotillus brachydens.*
No. 349 Univ. of Kansas. × 1.
Diagram of a fragment, showing elongated snout and broad bases of teeth.

Revised description: Nothing can be added to the original description. The creature is distinct from any other known form, but too little of it is known to fix its position. Williston (72) regards this as probably not distinct from *Crossotelos*, but the point is far from being decided.

FOREIGN FORM.

Genus DIPLOVERTEBRON Fritsch.

Diplovertebron punctatum Fritsch.

Fauna der Gaskohle u. der Kalksteine des Permformation Bönmens, vol. II.

Type: A few caudal vertebræ and fragments of limb bones. From the Gaskohle o Nyran.

This genus certainly belongs to the Embolomerus division and probably to the family *Cricotidæ*, but is so imperfectly known that little more can be said about it. The occurrence of this highly specialized form, with the equally specialized Pelycosaur *Naosaurus*, is strongly indicative of a connection of the Old and New Worlds near the close of the Permian. As indicated elsewhere, it is altogether probable that some members of the American fauna migrated to Europe and continued their existence there after the fauna had become extinct in America.

COMPARATIVE TABLES.

Table I. Showing the Characters of the Family Diplocaulidæ.

1. Skull large: triangular. Prosquamosal, parietal, supraoccipital and tabulare taking part in the formation of a large horn.
2. Facial region abbreviate, not over one-fifth the length of the skull.
3. Vertebræ complete, amphicœlous. Intercentra absent. Diapophysis and parapophysis, intracentral, separate. Zygosphene and zygantrum present.
4. Ribs two-headed; intravertebral.
5. Teeth conic; dentine not inflected; a large pulp cavity present.
6. Clavicle and interclavicle present, large, sculptured on outer surface. Coracoid small.
7. Limbs present. Humerus with entepicondylar foramen (?).

Table II. Contrasting the Characters of the Species of the Genus Diplocaulus.

I. *D. limbatus:*

1. Horns terminating in a point and curved inward at the end. The posterior edge of the skull more sharply concave.
2. Anterior edge of frontal bone but little anterior to the orbits.
3. Vomerine teeth arranged in a segment of a broad curve.
4. Anterior end of the skull broadly rounded.
5. Sculpture of facial region distinctly radial from a point between the orbits and nares.
6. Orbits larger.

II. *D. magnicornis:*

1. Horns terminating more bluntly or with spatulate ends, not incurved at extremities. Posterior edge of skull widely concave.
2. Anterior edge of frontal bone nearly midway between the orbits and nares.
3. Vomerine teeth arranged in a wide V, with the apex forward.
4. Anterior edge of skull more acute.
5. Sculpture of facial region not distinctly radial.
6. Orbits smaller.

III. *D. copei:*

Not determinate.

IV. *D. pusillus.*

Not determinate.

Table III. Contrasting the Characters of the Families of the Rhachitomous Division of the Temnospondyli.

I. *Eryopidæ:*
1. Small to large, reaching a length of from 2 to 2.5 meters.
2. Occipital condyles distinct.
3. Otic notch small.
4. Parasphenoid large, joining a basioccipital posteriorly.
5. A single sacral rib.
6. No dermal armor on the back.
7. Clavicle and interclavicle without sculpture.
8. Cleithrum present.
9. Humerus heavy; ends at right angles to each other; prominent processes present.
10. Femur with a prominent narrow ridge on ventral surface.
11. The two sides of the neural spine united.
12. Intercentra thick and heavy, nearly closing the notochordal canal.

II. *Trimerorhachidæ:*
1. Small, not over 500 centimeters long.
2. Occipital condyles united.
3. Otic notch small.
4. Parasphenoid large. Basioccipital not apparent.
5. Two functional sacral ribs (?).
6. No dermal armor on back.
7. Clavicle and interclavicle with external sculpture (?).
8. Unknown.
9. Humerus small, without condyles. Articular ends nearly parallel; without prominent processes.
10. Femur without ridge on ventral surface (?).
11. The two halves of the neural spine separate.
12. Intercentra very thin, leaving a large notochordal space. No processes on the intercentra for the rib.

III. *Dissorhophidæ:*
1. Small, not over 500 centimeters long.
2. Occipital condyles separate.
3. Otic notch represented by a large fenestra.
4. Parasphenoid reduced to a slender rod.
5. Two functional sacral ribs.
6. Dorsal armor composed of the laterally expanded neural spines smooth on upper surface, overlain by narrow dermal plates, which alternate with the spines in position.
7. Clavicles and interclavicle small, without sculpture.
8. Cleithrum very large.
9. Unknown.
10. Unknown.
11. The two halves of the neural spine united.
12. Intercentra thick, constricting the notochordal space. No processes on intercentra for the ribs.

IV. *Aspidosauridæ:*
1. Small, not over 500 centimeters in length.
2. Occipital condyles separate.
3. Otic notch small.
4. Unknown.
5. Unknown.
6. Apices of neural spines expanded, with a rough sculpture on the upper surface. No overlying dermal plates.
7. Unknown.
8. Unknown.
9. Unknown.
10. Unknown.
11. The two halves of the neural spine united.
12. Intercentra thick, constricting the notochordal space. Lateral processes for the head of the rib present.

Table III—Continued.

V. *Trematopsidæ:*

1. Small, not over 500 centimeters long, head disproportionately large.
2. Occipital condyles separate.
3. Otic notch small, completely inclosed, forming a fenestra.
4. Parasphenoid vestigial, or absent.
5. One (?) functional sacral rib.
6. No armor on back.
7. Clavicles and interclavicle without external sculpture.
8. Cleithrum probably present, unknown.
9. Probably as in *Eryops*.
10. Femur with prominent ridge on the posterior surface.
11. The two halves of the neural spine united.
12. Intercentra thick constricting the notochordal space. No processes on the intercentra for the ribs.

Table IV. Showing the Characters of the Embolomerous Cricotidæ.

1. Skull elongate, resembling that of *Archegosaurus*.
2. Nares not terminal, near outer edge of skull.
3. Orbits near middle of skull, looking upward and outward.
4. Intercentra complete, perforated disks, forming with the equally developed pleurocentra, embolomerous vertebræ.
5. Two (?) sacral vertebræ, the anterior one with a large rib.
6. Caudal vertebræ numerous. Chevrons coossified with intercentra.
7. Ilium reptilian, with a strong projection to the rear.
8. A close abdominal armor of imbricate scales, arranged in a chevron pattern.

Table V. Contrasting the Characters of the Genera of the Family Eryopidæ.

Eryops:

1. Large. From 2 to 2.5 meters in length.
2. Otic notch present.
3. Orbits proportionately small, a little posterior to the middle of the skull.
4. Nares some distance from the lateral and anterior edges.
5. Angle of lower jaw not produced beyond the quadrate.
6. Lower jaw wide vertically.
7. Skull covered with a coarse sculpture, especially strong on posterior portion.
8. Teeth irregular in size. Large tusks, in pairs, on prevomers, palatines, and maxillaries.
9. Dentine simply but strongly infolded.
10. Fine teeth on prevomers, pterygoids, and parasphenoids.
11. Ribs expanded, with an angular extension of the posterior edge.
12. A single sacral rib.
13. Pelvis narrow, with a long and narrow symphysis.
14. Spines of dorsal vertebræ with rugose apices.
15. Spines of caudal vertebræ bifurcate.
16. Humerus short with powerful processes; proximal and distal extremities at right angles.
17. Femur with narrow and high ridge on posterior face.
18. Feet short and wide.

Parioxys:

1. Small, not over 500 centimeters in length.
2. Otic notch present.
3. Orbits proportionately large, in posterior half of skull.
4. Nares more nearly terminal than in *Eryops*.
5. Angle of jaw continued behind the quadrate.
6. Lower jaw narrower, vertically, than in *Eryops*.
7. Only the skull known.

Anisodexis:

The specimen is fragmentary and can not be directly compared with the other members of the family.

Table V—Continued.

Acheloma:

1. Small, not exceeding 500 centimeters in length.
2. Otic notch absent.
3. Orbits of medium size; in the middle of the skull.
4. Nares near the lateral edge of the skull but not terminal.
5. Angle of the lower jaw not produced beyond the quadrate.
6. Lower jaw proportionately as wide, vertically, as in *Eryops*.
7. Skull with a moderately fine sculpture of pits, uniform in size and distribution over the skull, except at anterior end of the jaws, where it is absent.
8. Teeth subequal in size; some, in the premaxillaries, slightly enlarged.
9. Unknown.
10. Unknown.
11. Ribs flattened, expanded at proximal and distal ends but without extension of the posterior edge.
12. Unknown.
13. Unknown.
14. Spines of dorsal vertebræ expanded as if they were normally in contact with a dorsal plate.
15. Humerus short, resembles that of *Eryops* but without well formed, articular ends.
16. Unknown.
17. Unknown.

Table VI. Contrasting the Characters of the Genera of the Trimerorhachidæ.

Trimerorhachis:

1. Small, not exceeding 500 centimeters in length.
2. Skull elongate, flat, orbits small, in anterior half of the skull; without elevated rims; no interorbital depression.
3. Nares not terminal, but near anterior end.
4. No preorbital depressions.
5. Sculpture finely reticulate; edges of skull smooth.
6. Tabulare not prolonged into points. Posterior edge of skull not deeply concave.
7. Occipital condyle single.
8. A double row of teeth on maxillary. Teeth not enlarged except on the mandible and the palatine (?).
9. Intercentra thin, not constricting the notochord.

Zatrachys:

1. Small, not exceeding 500 centimeters in length.
2. Skull less elongate; elevated in orbital region; orbits in the posterior third of skull, surrounded by prominent rims; a strong interorbital depression.
3. Nares far back.
4. Deep preorbital depressions.
5. Sculpture not certain, surface destroyed in specimens preserved. Sutures very complicated, long processes from the edges of the bones interlocking strongly.
6. Tabulare prolonged into points. Posterior edge of skull more deeply concave.
7. Occipital condyle divided.

Only the skull known.

Table VII. Contrasting the Characters of the Genera of the Dissorhophidæ.

Dissorhophus.

1. Small, not exceeding 500 centimeters in length.
2. Skull not elongate, elevated, resembling in general proportions that of *Diadectes*. Orbits large, in the middle of skull, looking laterally. Otic notch closed, forming a fenestra.
3. Nares nearly terminal.
4. Parasphenoid a slender rod.
5. One tusk on each prevomer and palatine. Maxillary and mandibular teeth small, sharply conical.

Table VII—Continued.

Dissorhophus—Continued:

6. Twenty-one presacral vertebræ; 2 sacrals; caudals unknown, but tail short.
7. Dorsal vertebræ with the neural spines expanded into narrow plates overlying the back. Narrow dermal plates overlying and alternating with the neural spines, extending the full width of the body, with an elongate shield in front covering several vertebræ; rugose above.
8. Ribs double-headed anteriorly. Without posterior prolongation.
9. Cleithrum present, less expanded and thicker.
10. Scapula much expanded antero-posteriorly below.

Alegeinosaurus:

1–6. Only the middorsal region known.
7. Dorsal vertebræ with neural spines expanded but not wider than vertebræ. Small dermal plates overlying the neural spines directly, and each overlapping the preceding plate, not wider than the vertebræ. No enlarged anterior plate.
8. Ribs double-headed, with a long, slender posterior prolongation from a point near the upper end.
9. Cleithrum present, large as in *Cacops*.
10. Scapula less expanded below.

Cacops:

1. Small, not exceeding 500 centimeters in length.
2. Skull not elongate, elevated, resembling in general proportions that of *Diadectes*. Orbits large, looking laterally and upward. Otic notch closed, forming a fenestra.
3. Nares near anterior end, but more lateral in position than in *Dissorhophus*.
4. Parasphenoid small, almost vestigial.
5. One tusk on each prevomer and palatine. Maxillary and mandibular teeth small and conical, 22 to 23 in maxillary.
6. Twenty-one presacral vertebræ, 2 sacrals, 6 pygals, and 15 to 16 chevron-bearing caudals.
7. Dorsal vertebræ with neural spines expanded and wide antero-posteriorly. Dermal plates overlying and alternating with the neural spines. Narrow laterally, not greatly wider than the vertebræ; no enlarged anterior plate.
8. Ribs double-headed anteriorly, without posterior prolongation.
9. Cleithrum present. Thin and more expanded.
10. Scapula less expanded below; the interclavicles and clavicles more slender.

Table VIII. Showing the Characters of the Family Aspidosauridæ and the Genus Aspidosaurus.

1. Skull elongate-triangular, nose broadly rounded, resembling *Trimerorhachis*.
2. Apices of neural spines expanded into rugose, overlapping plates.
3. Intercentra without lateral processes for the head of the rib.

Table IX. Showing the Characters of the Family Trematopsidæ and the Genus Trematops.

1. Skull triangular, abruptly narrower at orbits.
2. Orbits in the middle of the skull, looking upwards.
3. Nares united with elongate antorbital openings.
4. A single medial opening at extremity of the nose.
5. Otic notches in form of fenestræ.
6. Maxillary and mandibular teeth subequal, conical. A single tusk on prevomer and two pairs of tusks posteriorly, probably on palatine and maxillary.
7. Humerus with an ectepicondylar and a short entepicondylar process. Condyles well developed.
8. Femur with a thin ridge on the posterior face.
9. Twelve tarsal bones.
10. Phalangeal formula of hind foot 2, 3, 3, 4, 3. Terminal phalanges without claws.

Table X. Showing the Characters of the Family Lysorophidæ and the Genus Lysorophus.

1. Small, snake-like, limbless (?).
2. Skull triangular, without temporal fenestræ or parietal foramen.
3. Anterior nares on outer edge of skull, nearly terminal.
4. Orbit lateral, incomplete, lower border wanting.
5. Quadrate inclined forward, bringing the articular surface beneath posterior edge of orbit.
6. Teeth small and conical, none enlarged.
7. Lower jaw two-thirds the length of skull.
8. Limbs and girdles absent (?).
9. Neural arch free from the centrum and divided into lateral halves.

Table XI. Showing the Characters of the Suborder Gymnarthria.

1. Skull completely over-roofed; no temporal foramina, but lower edge of skull cut away, as in some turtles. Lyra (*Cardiocephalus*) and parietal foramen (*Gymnarthrus*) present.
2. Quadrate free, not covered by prosquamosal.
3. Quadratojugal absent and prosquamosal reduced to small size or absent.
4. Basisphenoid and parasphenoid forming a large plate on lower surface of skull.
5. Teeth enlarged at posterior end of maxillary series, growing smaller to anterior end.
6. Lower jaw as long as skull.

Table XII. Contrasting the Characters of the Genera of the Family Gymnarthridæ.

Cardiocephalus:

1. Parietal foramen very small or absent.
2. Lyra present.

Gymnarthrus:

1. Parietal foramen large.
2. Lyra absent.

Table XIII. Showing Characters of the Family Cricotidæ and the Genus Cricotus.

1. Skull elongate, like *Archegosaurus* in form.
2. Nares not terminal, near outer edge of skull.
3. Orbits near middle of skull, looking upward and outward.
4. Intercentra complete, perforated disks, forming with the similar pleurocentra embolomerous vertebræ.
5. Two (?) sacral vertebræ, the anterior one with a large rib.
6. Caudal vertebræ numerous. Chevrons coossified with the intercentra.
7. Ilium reptilian, with a strong projection to the rear.
8. A close abdominal armor of imbricate scales.

MORPHOLOGICAL REVISION OF THE AMPHIBIA.

Suborder MICROSAURIA.

Family DIPLOCAULIDÆ Cope (p. 15).*

Genus DIPLOCAULUS Cope (p. 15). (Plates 1–5 and 12.)

Characteristic specimens: Nos. 4470, 4472 Am. Mus. Nat. Hist. and Nos. 610, 650, 651, and 652 University of Chicago.

Setting aside the extremely doubtful *Diplocaulus pusillus* Broili, the members of this genus are all characterized by the peculiar crescent-shaped head with elongated horns, formed by the tabulare. The genus has been described more or less fully by Cope (**45**), Broili (**4**), and Williston (**70**). The following description is based upon these accounts and upon personal observation of the specimens:

The *skull* is triangular or crescentic with a deep, posterior, concave emargination, and the angles of the skull are continued into great horns of solid bone. The nostrils are terminal and the orbits are far forward in the skull; the latter are small and round and look directly upward. The skull is very flat and even depressed in the parietal region. The whole upper surface of the skull and the lower jaw is marked by a sculpture of fine pits and reticulate lines; this seems to be the same over all parts of the skull. The mouth is short and very wide, the articular surface for the lower jaw being near the anterior third of the skull. The position of the bones is shown in figs. 1 and 2, pp. 17 and 18.

The *premaxillaries* are small elements forming the termination of the nose and not taking part in the border of the nares. They support a single row of teeth. Both Cope and Williston interpreted two small bones on the outer side of premaxillaries and forming the posterior rim of the nares as nasals. This permits the premaxillaries to unite directly with the frontals behind, a rather unusual relation. In specimen No. 4470 Am. Mus. Nat. Hist., *D. limbatus*, there is evidence of a suture across the elements, called by Cope and Williston the premaxillary, dividing it into an anterior portion, the premaxillary, and a posterior portion, the nasal. This would make the bone on the side the lachrymal instead of the nasal, and the relations would appear more normal. The only objection to this interpretation is that the lachrymal (?) is excluded from the orbit by the junction of the prefrontal and frontal.

The *frontals* are very large elements imperfectly divided on the median line and reaching from the nasals to a point far behind the orbits. They form the inner rim of the orbit, widely separating the prefrontal from the combined postorbital-postfrontal.

The *parietals* are separated on the middle line and inclose near their anterior border a small, parietal foramen. Rather narrow in the fore-and-aft direction, they are extended laterally in correlation with the developing horns.

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* Page references after names refer to the Systematic Revision.

The *supraoccipital* plates are extended in the same manner. They are separate and form the posterior edge of the skull. In three specimens the parietal of the left side has a greater extension to the rear than that of the right.

The *maxillaries* are short, not extending posterior to the orbits. They form the posterior edge of the nares and carry a single row of teeth.

The *jugals* are rather broad in front, forming the outer rim of the orbit, articulating with the postorbital-postfrontal and squamosal above and with the quadratojugal and prosquamosal behind. They are elongated in correlation with the developing horn.

The *squamosals* are smaller than the parietals, prosquamosals, and jugals, between which they lie; they are somewhat elongated, with the horns, but not so much so as the other bones.

The *prosquamosals* are large bones forming the bulk of the outer part of the horn. The posterior half of the outer edge is free and forms the edge of the skull; the anterior half is covered by the quadratojugal. On the other sides, the bone articulates with jugal, squamosal, parietal, and tabulare.

The *tabulare* forms the apex and a good portion of the horn; its anterior edge is wedged in between the parietal and prosquamosal, touching the extremity of the parietal.

The *quadratojugal* lies below the jugal and prosquamosal, and in the normal condition was directed somewhat downward, forming the edge of the fossa, into which fitted the coronoid process of the lower jaw. It supports the quadrate below and with the prosquamosal forms the postquadrate projection on the lower surface of the skull.

The *quadrate* is attached to the quadratojugals by the proximal end only; it passes upward and backward and is attached to the under side of the posterior part of the prosquamosal. On the lower surface the general position and relations of the bones are easily made out, but the exact course of the sutures can not be followed in any specimen.

The *premaxillaries* and *maxillaries* form the edges of the very short mouth, and each bears a single row of small, sharp, conical teeth. These have a slightly oval base in some cases, with a large pulp cavity, but without any approach to a labyrinthine arrangement of the dentine.

The *prevomers* form a small plate at the anterior end of the parasphenoid; they form the inner borders of the choanæ and bear a small row of sharp teeth, following in general the curve of the premaxillaries.

The *palatines* lie on the inner side of the maxillaries and form the inner border of the large palatine vacuities. They are separated by a distinct suture, in some specimens, from the ectopterygoid. A single row of fine teeth follows the curve of the maxillaries, but is separated from the maxillary teeth by a considerable space.

The *parasphenoid* is wedged in posteriorly between the pterygoids and the exoccipitals; the posterior end terminates in a sharp point which reaches nearly to the edge of the foramen magnum between the two occipital condyles. Anteriorly the bone narrows into a long bridge separating the two palatal vacuities, and probably terminates in a sharp point, but the sutural connection with the vomers and palatines can not be made out.

The *exoccipitals* support the occipital condyles. They may be considered as formed of two parts, an inner carrying the condyle and forming the border of the foramen magnum and an outer elongated process, probably

including the opisthotic, which unites with the skull above, most extensively with the parietals. Between the outer processes of the exoccipitals and the supraoccipitals above are two small openings, which probably admitted blood vessels to the brain cavity. Near the condyle there is a foramen for the vagus nerve.

The *pterygoids* are broad posteriorly, articulating with the parasphenoid and exoccipitals; the broad posterior portion separates the palatal vacuities from the otic notches behind. The outer end divides into two parts, one of which extends backward to the quadrate and borders a deep pit behind. The other extends forward on the outer side of the palatal vacuities and probably unites with the palatines and vomers anteriorly. The sutures can not be made out.

The *ectopterygoid* is a distinct element separated from the pterygoid, palatine, and maxillary by sutures.

There are four vacuities or cavities on the lower surface: the internal nares, far forward, surrounded by the vomers, the palatines, and the maxillaries; the large, palatal vacuities surrounded by the vomers, palatines, pterygoids, and parasphenoid; the cavity for the coronoid process of the lower jaw, bordered on the outer side by the quadratojugal and on the inner side by the pterygoid; two deep pits, posterior to the pterygoids, excavated in the bones of the horns, which may have sheltered external gills.

The *lower jaw* is slender and short, not over one-fourth or one-fifth of the length of the skull. The two halves are coossified at the symphysis; it is impossible to make out the component elements of each ramus. The outer surface is marked by a sculpture similar to that on the skull. There is a single row of teeth except at the anterior end, where there are two rows.

Vertebral column: There are more than twenty vertebræ in the column. Specimen No. 4472 Am. Mus. Nat. Hist. has nineteen consecutive vertebræ extending from the first to an anterior caudal. No. 652 University of Chicago has twenty vertebræ, "mostly continuous." It is probable that there were more than this, perhaps as many as thirty. All the vertebræ are marked on the sides and lower surface of the centrum by a most intricate and delicate sculpture of fine, interlacing lines (see plate 1). In the caudal vertebræ this sculpture is present on the neural arches and the hæmal processes, but is coarser and more rugose. In the series preserved at the American Museum the vertebræ show a gradual increase in both length and breadth to the ninth or tenth, from which point they gradually become more slender.

The *first vertebra*, commonly called the *atlas*, is longer than the second and of a somewhat pentagonal outline. At the anterior angle is a tube-like projection from the edges of the neural canal, which fits into the foramen magnum. The faces for the occipital condyles are elongate oval, and look outward and slightly upward. The neural spine is very broad and low. It bifurcates posteriorly, sending back processes which reach nearly across the second vertebra and embrace its spine. A small process on the anterior end of the spine of the second vertebra fits into a notch at the point of bifurcation of the first spine. The posterior zygapophyses are well developed and between them is a strong zygantrum. On the lower surface is a broad keel which is reduced in size anteriorly until it disappears near the anterior end. There is no evidence of ribs attached to the first vertebra.

The *second vertebra* (axis?) is quite short and fits very closely against the first. The low neural spine has a deep pit, such as occurs in all the dorsal

vertebræ, and is regarded as the possible attachment of a cartilaginous neural spine. The anterior and posterior zygapophyses and the zygosphene and zygantrum are well developed. There is a low keel on the lower surface which is somewhat broadened at the anterior and posterior ends. On the sides are two well-developed processes for the double-headed ribs; the lower is attached to the centrum and the upper to the neural arch.

From this point the dorsal vertebræ are quite similar. The centrum is elongate with the lower surface concave antero-posteriorly, and in the large specimens nearly flat from side to side near the middle. In smaller specimens the lower surface is convex from side to side. There is no trace of a keel on the centrum after the second vertebra. The neural spine is heavy and low, with a deep pit, possibly for the attachment of a cartilaginous spine. In the American Museum specimen, No. 4472, the processes for the ribs remain distinct to the twelfth or thirteenth, where they fuse and form a strong transverse process, which is quite elongate, with a broad distal end. The last trace of this lateral process disappears on the eighteenth.

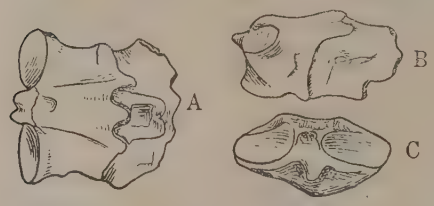

FIG. 21.—*D. magnicornis*. After Broili. × ¾. Atlas and axis. A, from above; B, from side; C, anterior view of atlas.

The vertebræ immediately posterior to the second either do not have the pit or it is very much reduced. One, possibly the third, has the spine elevated and rather rugose. The neural arch is very wide, and extends out directly into the transverse process, which bifurcates into upper and lower parts for the rib. The next vertebra following has the spine lower, and there is a deep pit, narrow anteroposteriorly but extending across the spine; the bottom and sides of the pit are smooth. The spine extends much farther posteriorly than the centrum; the posterior end is wider and incloses the anterior end of the following vertebræ. The articular faces of the zygapophyses of all the dorsal vertebræ are nearly horizontal. The zygosphene and zygantrum continue through the series. In the majority of the vertebræ the elongate diapophysis and parapophysis rise independently, the former from the arch and the latter from the mid line of the centrum.

FIG. 22.—*D. magnicornis*. No. 4472 Am. Mus. × ¾.

A. Sixteenth to nineteenth dorsal vertebræ from below.
B. Lateral view of second vertebra shown in A.

The *seventeenth vertebra* is markedly different from those preceding. The neural spine is lower, and has not the deep pit or notch as in the anterior dorsals. The lower face of the centrum is nearly flat, but is excavated by a deep and wide pit. The posterior edge of this vertebra is thickened and rugose, and articulates by an interlocking suture with the succeeding vertebra. This is probably the point of attachment of the posterior limbs and is the degenerate sacrum.

The centrum of the eighteenth is of much smaller diameter but of greater length than the anterior vertebræ, and has very prominent neural and hæmal spines. These are high and narrow with expanded extremities and give the vertebra a flattened appearance vertically. The distal ends of the neural and hæmal spines are heavy, with flat rugose faces, which have the appearance of having been attached to heavy plates of cartilage or perhaps bone. On the last vertebræ observed the distal ends of the hæmal spines are so elongate that they touch the spines of the adjacent vertebræ.

The *ribs* are relatively heavy and short, with little curvature and widely separate capitulum and tuberculum.

The *clavicles* and *interclavicle* (plate 12, fig. 3) unite to form a thin, heart-shaped plate, covered on the outer surface with a sculpture similar to that of the skull. The clavicles overlap the anterior end of the interclavicle below. From the outer edge of the clavicle a smooth, conical process extends upwards and inwards, possibly for the attachment of the scapula. The interclavicle is rhomboidal, with no posterior prolongation; the posterior edge is marked as if by the squamous attachment of some element, unknown as yet.

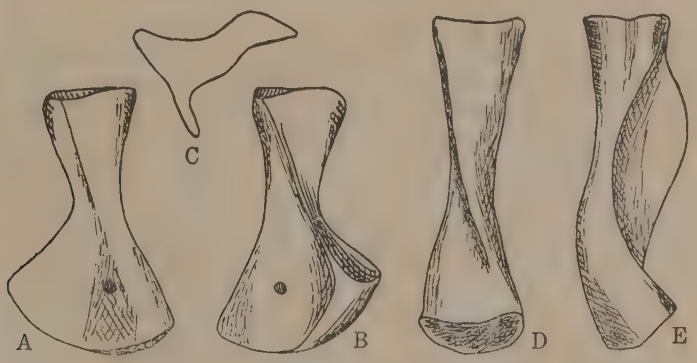

FIG. 23.—*D. magnicornis*. After Williston. No. 652 Univ. of Chicago. × ¾.

A. Dorsal view of right humerus.
B. Lower view of same.
C. Cross-section of proximal end of same.
D. Posterior view of femur.
E. External view of same.

The coracoid: Williston has discovered a small oval plate lying on the upper side of the clavicle in specimen No. 652 University of Chicago, and less perfect remains of this bone are found in specimens No. 4539 and 4748 Am. Mus. It is thin, nearly oval in shape, with a slight thickening of the posterior part to receive the humerus. A small foramen pierces the inner side, back of the middle and not far from the edge.

The *scapula* is unknown.

Previous to 1909, none of the numerous skeletons of *Diplocaulus* collected had any trace of associated limb bones, and the animals were regarded as limbless. Dr. Williston reports (70) finding limb bones with several specimens, in what he regards as unquestionable association. Specimens Nos. 650, 651, and 652 University of Chicago show these bones.

The *humerus* is rather short, without well-formed articular surfaces. The two extremities are expanded and turned at an angle of 45° to each other. The distal end is larger and more thickened than the proximal and

is pierced by an entepicondylar foramen. From the outer side of the distal end a sharp ridge runs up the ventral face nearly to the proximal end.

This is the single case among the *Amphibia* from the Texas Red Beds, or their equivalent elsewhere, in which an entepicondylar foramen has been found in the humerus. The opening in the humerus of *Acheloma cumminsi* is purely accidental in the opinion of Williston, Broom, and the author. For this reason it is possible that the humerus may be reptilian and in accidental association.

The *femur* is more slender than the humerus, with the proximal and distal ends subequal and only moderately expanded. A thin high crest in the posterior surface occupies the middle three-fifths, reaching to neither extremity. The lower end is bent strongly backwards, so that the articular surface looks somewhat backwards as well as downwards. The whole bone recalls that of *Eryops*.

Fragments of the *tibia*, *fibula*, and *metapodial* bones have also been discovered, but little can be made out concerning them. Limbs such as are indicated by these bones would have been very short and practically useless to the animal, being clearly degenerate. The posterior limb was even more reduced than the anterior.

Diplocaulus, in the flesh, must have been one of the most curious creatures of its time. The body was fairly short and heavy; the flat, triangular head very disproportionate in size, and the limbs weak and almost useless. The greatest number of vertebræ known is twenty, but if we add one-half more the body of the animal must still have been absurdly rotund and stubby. It is probable that the animal could not raise its enormous head from the ground except by a short, paroxysmal effort. The head must have been pushed forward through the slime and mud at the bottom of some small body of water, as the animal fed on small, slow-moving creatures or vegetation. There is no hint of the use of the enormous horns; it has been suggested that they protected external gills, but there is no reason to assume the presence of external gills except the pit, which lies on the lower surface of the horns posterior to the pterygoid. It is more probable that these animals were under the influence of the same conditions which caused the development of excessive structures in contemporaneous reptiles and amphibians. Jaekel's suggestion (**56**) of the derivation of *Diplocaulus* from forms like *Ceraterpeton* and *Diceratosaurus* is very probably correct.

The position of *Diplocaulus* is uncertain. In many particulars it resembles the *Microsauria*, but departs radically from the order in others. In the skull and complete vertebræ the connection with the *Microsauria* is strongly indicated, but, as pointed out by Williston, the ribs are notably different. The *Microsauria* have single-headed ribs attached intervertebrally; but in *Diplocaulus* the ribs are two-headed and are attached to intravertebral diapophyses and parapophyses. Williston (**70**) believes that this is a sufficient reason for placing *Diplocaulus* in a group of higher than family rank, but hardly sufficient to exclude them from the order *Microsauria*. He is inclined to attach rather more weight to the method of rib articulation than is usual. Moody (**61**) would place *Diplocaulus* in a distinct new order, *Diplocaulia*, which he places doubtfully in a subclass *Holospondyli*, thinking that it may belong in the *Stegocephalia*. Since *Diceratosaurus* Jaekel appears to connect, in many ways, the undisputed Microsaurian *Ceraterpeton* with *Diplocaulus*, I have retained the latter as a family of the *Microsauria*.

Diplocaulus magnicornis Cope.

The description of the genus given above is drawn from both of the well-known species. *D. magnicornis* seems to have been somewhat larger than *D. limbatus* and to be very clearly distinguished by the form of the skull and the relations of the bones. The following measurements are drawn from several specimens:

	mm
No. 4472 Am. Mus.:	
Breadth across horns	400
Length on mid-line	131
Length three middorsals	72
No. 4539 Am. Mus.:	
Breadth across clavicles and interclavicle	129
Anteroposterior length of interclavicle	100
No. 652 Univ. of Chicago:	
Breadth across horns	348
Length on mid-line	120
Length of atlas	20
Greatest expanse of same	32
No. 652 Univ. of Chicago—Continued:	mm
Length of second vertebra	11
Expanse of transverse processes	46
Length of third vertebra	13
Expanse	48
Length of fourth vertebra	14
Expanse	50
Length of fifth vertebra	17
Expanse	48
Length of sixth vertebra	20
Expanse	48
Length of seventh vertebra	21
Expanse	46

Diplocaulus limbatus Cope.

The distinction between this species and *magnicornis*, suggested by Cope and based on the character of the quadratojugal and the otic notch, does not seem to be determinative; the conditions described by him are due to the pressure and are not correlated with the other differences. Measurements are given in the original description of the species.

Genus ERYOPS Cope (p. 24). (Plates 4–10.)

Characteristic specimens: Nos. 4673, 4183, 4180, 4893 Am. Mus. Nat. Hist. Cope Coll. and No. 117 University of Chicago.

The genus *Eryops*, though one of the most abundant forms in the Texas beds, has but one well-known species, *E. megacephalus;* other species have been named, but are so insufficiently known as to make their determination uncertain. Several other genera and species have been named from vertebræ and parts of skeletons which have later been shown to be synonyms of *Eryops;* such are *Rhachitomous valens* Cope and *Epicordylus erythroliticus* Cope. *Parioxys ferricolus* Cope was regarded by Cope himself as a young *Eryops*, but it seems to have certain distinctive characters and is considered in this paper as a distinct genus and species.

The following description drawn from several specimens applies entirely to *Eryops megacephalus*. Aside from the descriptions by Cope, two papers by Broili (3) and Branson (2) have been freely drawn on.

The *skull* is not disproportionately large, as is so common in the Paleozoic and Mesozoic *Amphibia*. The surface of both skull and jaws is covered by a very rough sculpture of deep pits, which become larger on the posterior portion of both skull and jaws. The orbits are located in the posterior half of the skull, and look upward and but slightly outward. The upper edge is marked off from the depressed interorbital region by slightly elevated ridges. The articular region extends well back of the occipital condyles, and there are well-developed otic notches. The bones of the skull are rather thin, especially in the preorbital region, so that this part is frequently broken and missing. The nostrils are set well back from the anterior end of the

skull and look outward and upward. There is no trace of lyra or mucous grooves.

The rugose condition of the skull makes it difficult to trace the sutures of the upper surface, but Branson (2) has worked out most of them in specimen No. 117 University of Chicago, fig. 24. These correspond, in a general way only, with those of a small specimen, No. 4310 Am. Mus., regarded as a young *Eryops* (fig. 26).

The *premaxillaries* are large and form the extremity of the nose. The character of the sculpture is shown in plate 8.

The *nasals* extend far forward in the middle line, and then recurve to take part in the edge of the nares; several specimens show the same notch in the suture line just inside the nostril. Posteriorly they seem to contract and to include the sharp anterior end of the frontals.

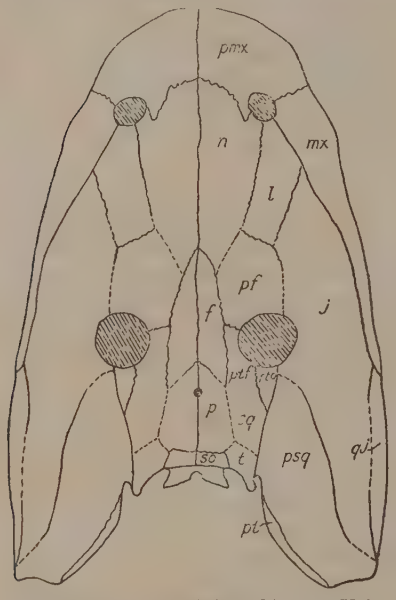

FIG. 24.—*E. megacephalus.* No. 117 Univ. of Chicago. × $\frac{1}{6}$ circa.
Upper view of skull, showing sutures slightly modified from Branson. Lettering as usual.

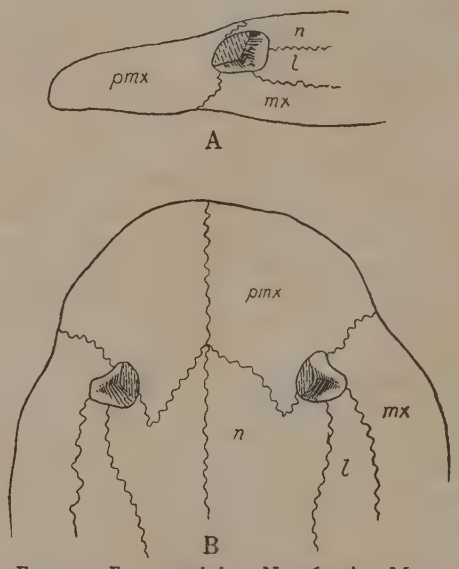

FIG. 25.—*E. megacephalus.* No. 4673 Am. Mus.
A. Lateral view of anterior part of nose. Lettering as usual.
B. The same, anterior part of nose, showing sutures.

The *septomaxillary:* Within the nares of specimen No. 4673 Am. Mus. are small elements bent at right angles, so that they form the back and bottom of the nares. These are the turbinated bones of Cope or the septomaxillaries of Swinnerton and Howse.

The *lachrymals* are narrow bones, taking part in the posterior edge of the nostrils, but not, according to Branson, reaching back to the orbits.

The *maxillaries* are more elongate than is indicated in Branson's figure; on the lower face they reach back to a point posterior to the orbit.

The *prefrontals* are nearly square and form the inner anterior edge of the orbit. They meet the postfrontals and exclude the frontal from any part in the orbit.

The *frontals* are relatively small, the two bones coming to a point anteriorly and inclosed by the nasals. The posterior ends include the anterior ends of the parietals.

The *postfrontals* are not well known; the sutures of the posterior ends have not been made out.

The *postorbital* is a small triangular element between the postfrontal, jugal, and prosquamosal.

The *jugal* is elongate, reaching from the maxillary and lachrymal in front, nearly or quite to the posterior edge of the skull. Branson figures it as excluded from the posterior part of the outer edge of the skull by an elongate quadrate, but in specimen No. 4673 Am. Mus., in which the sutures of the lower surface are clearly shown (plate 7, fig. 1), the quadrate appears as a very short element, taking part only in the extreme posterior part of the edge of the skull, and the quadratojugal reaches nearly to the posterior end. The jugal forms the lower edge of the orbit.

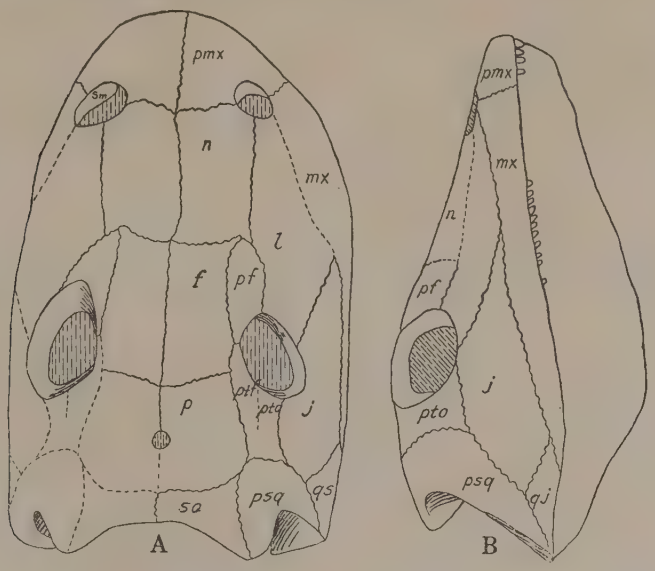

FIG. 26.—Skull of *Eryops* sp. No. 4310 Am. Mus. × ⅔.

A. Upper view, showing sutures as far as they can be made out. *sm*, septomaxillary.
B. Lateral view of same specimen shown in A.

The *prosquamosal* forms the bulk of the posterior angle of the skull. The inner side is smooth and the outer surface is marked by a peculiarly coarse sculpture. The bone showing below the prosquamosal on the inner side is not the *quadrate*, as suggested by Branson, but the posterior end of the pterygoid.

The outlines of the *parietals*, *squamosals*, and *tabulare* are uncertain; the latter element has not been proven to exist, but is probably present. Contrary to Branson's statement, a parietal foramen is present, though it is small compared to the size of the skull.

The *supraoccipital plates* are small and form the posterior edge of the skull.

The lower surface of the skull is shown almost perfectly in specimen No. 4673 Am. Mus. (plate 7, fig. 1). This skull was found in a loose, sandy gravel, and the matrix fell away easily from the bones, leaving them naturally clean; the sutures are as readily traced as in a recent skull. Unfortunately, the

upper surface is somewhat injured by a transverse break. In general, the position of the bones is as made out by Branson (2, fig. 11*a*), but the course of the sutures could not be exactly traced in his specimen. In plate 7 is shown the lower surface of specimen No. 4673 Am. Mus., on which the course of the sutures was traced in ink before the photograph was made.

The *premaxillaries* show nearly as widely on the lower surface as on the upper. On the right side, a posterior extension reaches nearly, but not quite, to the anterior edge of the internal opening of the nostril; on the other side it does not extend so far. There are no tusks on the premaxillaries, but just within the tooth line and near the symphysis there is a deep pit in each bone. The teeth on the anterior portion are small, but are slightly larger near the middle of the bone. In the vicinity of the premaxillary suture the teeth of both the premaxillary and maxillary are smaller.

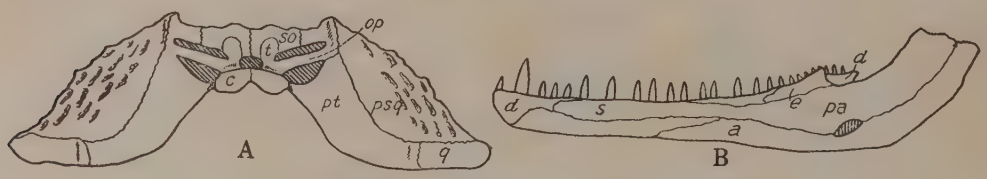

FIG. 27.—*Eryops megacephalus*. No. 117 Univ. of Chicago.

A. Posterior view of skull, modified from Branson. × ⅔. *so*, supraoccipital plate; *t*, tabulare; *op*, opisthotic; *pt*, pterygoid; *psq*, prosquamosal; *q*, quadrate.
B. Inner view of lower jaw. After Branson. × ⅓. *d*, dentary; *s*, splenial; *e*, coronoid; *pa*, prearticular; *a*, angular.

The *maxillaries* extend back to a point opposite the posterior end of the palatal vacuities. At the anterior end they form the outer edge of the choanæ and, uniting with the prevomers before and behind, complete the border of the opening. Just posterior to the choanæ they widen and are separated from the palatal vacuities by a very narrow extension of the pterygoid. On this widened portion and just posterior to the opening is a slightly raised space bordered by an elevated rim; within the rim are the bases of two tusks. It is apparent that one of these was functional, while the other was absent or growing; the same thing is true of the tusks on the palatine bone. It is perhaps noteworthy that the same condition occurs in the double canine tusks of *Dimetrodon*, *i.e.*, the posterior one is functional on one side while the anterior one is functional on the other side, and *vice versa*. There are two large teeth on the edge of the bone just opposite the tusks.

Posterior to the tusks, the edge of the bone turns outwards, then backwards and obliquely forwards again, nearly to the edge of the skull; posterior to this point the maxillary shows only as a very narrow edge on the skull. From the point where the posterior edge of this part of the maxillary curves around the palatine, a suture runs forward on the maxillary, but disappears. It is present on both sides. There may have been a division of the bone in youth, but the suture is incomplete in this specimen.

The teeth are irregular in size, generally larger in the anterior parts of the maxillary and premaxillary and becoming smaller posteriorly, but it is noticeable that there is a great diversity in size all through the series; this is probably due to the constant loss and replacement of teeth. The teeth are conical, little recurved, and show a decided but simple unfolding of the dentine.

The *palatines* are short and narrow, reaching from the point of union of the pterygoids and maxillaries about half-way to the internal nares. Near the anterior end is an elevated area with raised rim, supporting a pair of tusks similar to those on the maxillary.

The *prevomers* are large plates, reaching from the posterior edge of the premaxillary to a point well back of the internal nares. The union with the parasphenoid is not shown, but it is apparent from other specimens that the latter ended in a sharp point anteriorly. On each bone, near the anterior inner corner of the internal nares, is a pair of tusks on a raised surface, similar to those on the maxillaries and palatines. Running across the two bones, from one of these areas to the other, is a low ridge, formed by a thickening of the bone and covered with numerous fine teeth. Similar patches of fine teeth lie in front of the tusks and run from the posterior edges of the tusks around the opening of the nares and back to join the teeth on the pterygoid. Each prevomer divides posteriorly and receives a long, slender prolongation of the pterygoid.

The *pterygoids* are tripartite. An inner process unites with the stout basipterygoid processes of the parasphenoid. The anterior portion forms the main part of the bone; it is a wide, flat plate uniting with the palatines, maxillaries, and prevomers externally. The inner edge is concave and forms the border of the great palatine vacuity. This edge is thickened, and bears on its whole length a series of small teeth; the series is continuous, anteriorly, with the teeth on the prevomers. The posterior portion is turned so that it is a vertical plate convex toward the mid-line and uniting with the prosquamosal above and the quadrate behind.

The *parasphenoid* unites by strong sutures with the basioccipital behind and with the pterygoids laterally. This posterior portion is not large, but it is thickened and there is a considerable longitudinal depression on the median line. The anterior portion, forming the bridge between the two palatine vacuities, is relatively slender and ends in a rather sharp point anteriorly.

The *basioccipital* is a small but well-defined bone uniting strongly with the parasphenoid. The interpretation given by Broili (3) (plate 8) of this region, was based on a crushed specimen; the pterygoids do not meet in the middle line and there is a single basioccipital bone behind the parasphenoid instead of two exoccipitals.

The *quadrate* is a small, triangular bone between the pterygoid and quadratojugal, on either side, and the prosquamosal above. It appears only on the lower surface and for a short distance on the inner side of the posterior prolongation. The condyles are shallow and the whole articulation with the lower jaw was weak.

On the *posterior surface of the skull* the foramen magnum appears as a relatively very small, oval opening. The condyles are short and stout, with concave articular faces looking slightly inward. The exoccipitals are described by Branson as forming the edges of the foramen magnum, except above, where it is completed by the supraoccipital plates. From the outer side of the exoccipitals, a slender process runs out to the tabulare angle of the skull, and between it and the supraoccipital plates above is a good-sized foramen. In the otic notch, below, a stapes of good size has been found in specimen No. 3060 University of Michigan.

The sutures of the mandible are shown in specimen No. 117 University of Chicago. The bones are described as follows by Branson:

"The sutures in the mandible of *Eryops* have never before been determined, but in all of the specimens in the Walker Museum most of them are distinct. The suture between the prearticular and the splenial has not been definitely located.

"The articular is short and thick. It is covered on the outside by the angular and surangular, and on the inside by the angular and prearticular. The articular surface is convex, the convexity passing diagonally forward from the posterior inner corner. The coronoid is very small, and is situated in front of the supra-meckelian foramen, as in *Anaschisma*. The dentary is slender, sculptured anteriorly and smooth posteriorly. The posterior end of it projects a little way behind the coronoid. There is a high, thin parapet on the upper side of the outer part of the bone, and the outer edges of the teeth are imbedded in it. The angular forms the greater part of the outside of the mandible in front of the supra-meckelian foramen. The suture between the angular and surangular has not been definitely determined. The splenial is slender and very thin. It projects above the inner edge of the dentary anteriorly, but gradually descends posteriorly. The portion in front of the angular seems to be an element separate from the dentary. The suture between it and the dentary appears to be near the lower edge of the jaw on the outer side. As previously stated, this element seems to be distinct in *Anaschisma*, but the evidence in neither case is conclusive.

"The internal mandibular foramen is small, oval, situated between the angular and prearticular directly below the anterior end of the supra-meckelian foramen. The supra-meckelian foramen is elongate and narrow.

"The sculpture on the outside of the mandible consists of longitudinal ridges and furrows above, but these become coarser and have more of the pitted character below."

A small skull, No. 4180 Am. Mus. Nat. Hist. Cope Coll., is possibly that of a young *Eryops*, but, if so, the skull underwent considerable change of form and proportions during development. The posterior angles do not project anywhere near so far backward, not reaching beyond the extremities of the tabulare; the orbits are farther back than in the adult, and the nares are closer to the anterior end and more nearly strictly superior. The character of this skull is shown in plate 8 and fig. 26. The positions of the sutures are made out from the centers of radiation of the bones, and are approximate only. They differ markedly in some places from the sutures drawn by Branson for the adult *Eryops*.

The vertebral column: The number of presacrals is not exactly known. In specimen No. 4280 Am. Mus. there are 21 counted vertebræ, but a break leaves room for two or three and the first vertebra is missing, so there were at least 23 or 24. Branson calculated 25 or 26 for the Chicago specimen No. 117. In the specimen used for restoration, No. 4893, only 21 presacral vertebræ could be placed; this is perhaps short of the normal number.

The rhachitomous vertebræ of *Eryops* are well known, and the typical form need not be redescribed in great detail.

The *first vertebra* is represented in three specimens by the neural arch alone. The pleurocentra and intercentrum being absent, the latter was probably present, the former not. The neural arch consists of two halves with broad faces below, in part for the occipital condyles, and slender dis-

tinct spines above. The two halves are separated in some specimens and united below in others; this seems to be a character of age. The spines are directed backwards at a considerable angle, and lie on either side of the large spine of the second vertebra. This is a common structure in many of the Stegocephalia; it occurs in *Trimerorhachis* and others. The degree of inclination varies in different specimens and is probably extreme in the specimens figured. On each half of the vertebra there is a small process opposite the neural canal, which probably articulated with the skull or with a rudimentary vertebra, in the position of the proatlas of the reptiles. The posterior zygapophyses are small and articulate, with equally small processes on the second vertebra. There was, without doubt, a large intercentrum between the first and second vertebræ.

FIG. 28.—*Eryops megacephalus*. No. 4180 Am. Mus. × ½.
A. Lateral view of the first five vertebræ.
B. Anterior view of neural arch of first vertebra.
FIG. 29.—*Eryops megacephalus*. No. 4893 Am. Mus. × ⅜.
Sacral vertebra from left side.

FIG. 28.

FIG. 29.

The faces of the occipital condyles look downward as well as inward, requiring the presence of an exceptionally large intercentrum for the first vertebra; this intercentrum bore the main faces for the occipital condyles.

The *second vertebra*, the axis, has the neural spine nearly twice as wide, anteroposteriorly, as the normal dorsal vertebræ. The anterior edge of the spine is thin, and separates the two halves of the spine of the first vertebra. The posterior zygapophyses are normal in size. The transverse processes stand out prominently from the sides of the neural arch and bear faces for the single-headed rib. The intercentrum is normal, but does not bear a facet on the posterior edge for the lower part of the rib head.

The *third vertebra* is normal.

The *fourth vertebra* resembles the others in all respects but the neural spine; this is only one-half the size of those before and behind it. The upper end seems to fit into a notch formed by the overhanging anterior edge of the fifth. This peculiar character is observable in three specimens (see fig. 28 A).

From the *fifth* to the *eighteenth*, the vertebræ are very similar in form. The neural spines are slender, with somewhat expanded and rugose apices, which lie nearly in a straight line. The dorsal vertebræ of *Eryops* have been

repeatedly described and are well known. Each vertebra consists of four parts: neurocentra bearing the spine, zygapophyses, and transverse process; two lateral elements, the pleurocentra; and an inferior element, the intercentrum. The homology of these elements has occasioned an exhaustive discussion. Without reviewing the matter, it may be stated that it is conclusively settled that the pleurocentra are the basi-dorsal elements of Gadow, and that the hypocentrapleurale do not occur in *Eryops*.*

From the *fourth* to the *eighth*, the transverse processes grow gradually longer and then diminish slowly to the eighteenth. On the first three presacrals the transverse processes are still as large as on the eighteenth, and on the first presacral there is a small free rib.

There is but a single *sacral vertebræ;* Branson reports two, but this is clearly a mistake. The spines and zygapophyses do not differ from those of the dorsal vertebræ; the transverse process is very large, with a wide face for the rib, and there is an equally large face on the intercentrum instead of the usual very small one. A face on the posterior edge of the pleurocentrum shares partly in the articulation of the rib. The only evidence of an approach to a sacrum is, that the posterior edge of the much enlarged intercentrum of the sacral vertebra is thickened and closely applied to the thickened anterior edge of the intercentrum following; they do not seem to have been attached except by a heavy cartilage.

The *caudal vertebræ* were very few in number. The greatest number preserved in any specimen is ten, but as the last of these are already quite small, it is probable that there was not more than double this number. The intercentrum of the first caudal is elongate, but the others are normal in size. Chevron bones appear on the seventh intercentrum and continue to the end. They are fused with the intercentra, perforate at the upper end, and the largest, the anterior ones, are nearly two-thirds the length of the spine of the vertebræ to which they belong.

The spines of the anterior caudals terminate in a heavy knob, as do those of the dorsal series, but on the fourth the spine begins to bifurcate, and from this to the tenth, the last caudal known, the apices are double, the two parts developed as smooth conical processes. It was upon this character that Cope founded the genus and species *Epicordylus erythroliticus*, a mistake which he recognized and corrected so far as to regard *Epicordylus* as a synonym of *Eryops*.

The *ribs* of *Eryops* are not completely known. The first evidence of rib attachment is on the second vertebra, but it is not improbable that there was a rib on the first. The heads of all are broad, but not distinctly divided; the tubercular portion is thickened, and was applied to the end of the transverse process. The capitular portion was thin, not separated from the tubercular part by a notch, and in the mid-dorsals, at least, reached downward and forward to fit into a notch on the posterior edge of the intercentrum.

The *dorsal ribs* are elongate and flattened in the middle portion; the posterior edge is continued backward in the middle third, forming a triangular projection over the succeeding rib and a strong protection for the thorax. Ribs were present on all the presacral vertebræ, but the form of the posterior ones is not known. The last vertebra carries, in one specimen, a small, free rib.

*The chief papers in this discussion are reviewed in Baur's note on *Archegosaurus* in the American Naturalist for 1897, p. 875, and in Branson's Structure and Relationships of the American Labyrinthodontidæ, Journ. Geol., vol. XIII, 1905, p. 568.

The single *sacral rib* is large, with a single head, divided into distinct facets, which lie at an angle to each other and fit the facets on the pleurocentrum and transverse process, and the intercentrum. A slight constriction forms a neck which separates the head from the body of the rib. The body is flattened and curved to the rear; the outer surface fits accurately into a depression, which runs obliquely across the inner face of the ilium from above backwards and downwards. There is no rugosity on either bone at the points of contact, but the two fit very closely. This relation of the sacral rib to the ilium is of great importance, as on it depends the position of the whole pelvis. The relationship is confirmed by its occurrence in three specimens.

The *caudal ribs* are free as far back as the fifth vertebra, but ribs are absent beyond this.

The shoulder girdle and fore limbs (No. 4186 Am. Mus.): This is the specimen figured by Cope. The anterior portion of the *clavicle* is broad and some-

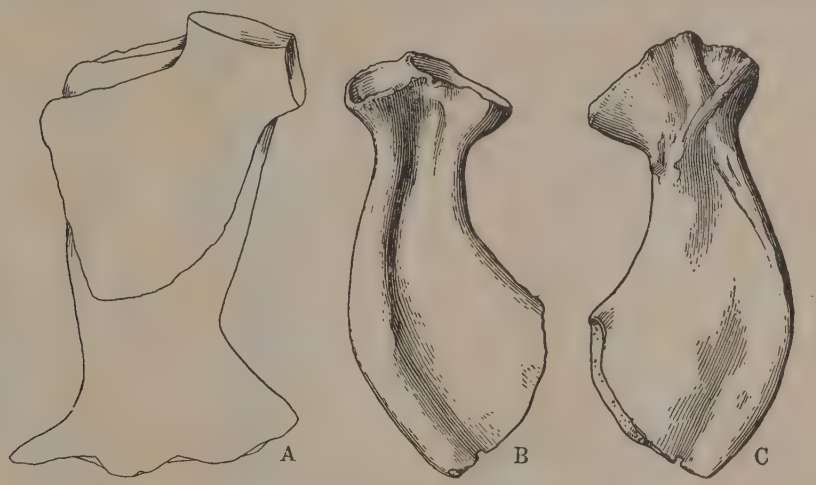

FIG. 30.—*Eryops megacephalus.*

A. Inner view of left sacral rib and ilium, showing relation of bones. No. 4292 Am. Mus. × ¾.
B. Inner view of left sacral rib. No. 4307 Am. Mus. × ½.
C. Outer view of same.

what convex outward; the bones of the two sides overlap in the specimen, and probably did so to some considerable extent in the living animal. The posterior third is bent almost at right angles to the anterior part, and lies on the upper edge of the scapula, overlapping it somewhat on the inner side; this part of the clavicle lies beneath the anterior end of the cleithrum. The edges of the clavicle are thin, and the anterior and posterior edges show a tendency to fray out into thin projections, but a strengthening ridge runs its full length, about one-third of the way from the top. The outer surfaces of both the clavicle and interclavicle are smooth and without radiating ridges.

The *interclavicle* is rhomboid in form without posterior prolongation; the anterior edge carries a few blunt, flattened spines.

The *scapula* shows no evidence of separate procoracoid or coracoid bones; these were apparently cartilaginous. The anterior end is slightly convex in most specimens. The posterior end is but little widened and the upper

and lower edges of the blade are nearly parallel. The lower edge is continued forward on the bone, forming a sharp prominence just over the cotylus for the humerus. There are two foramina perforating this part of the bone; a deep triangular pit lies just beneath the prominence and above the cotylus; a foramen penetrates the bone in this pit and opens on the posterior side in a deep, crescent-shaped pit. Another foramen lies just anterior to the prominence, and, perforating the bone, opens in the same crescentic pit on the posterior surface.

The *cleithrum* is a slender rod anteriorly, lying on the upper side of the scapula and outside of the distal end of the clavicle. The distal end is expanded into a thin, fan-shaped plate, which is closely pressed to the outer surface of the scapula and is even fused with it in old specimens. This is especially well shown in specimens No. 4037 Am. Mus. and No. 182 University of Chicago, the latter the type of *Eryops latus* Case.

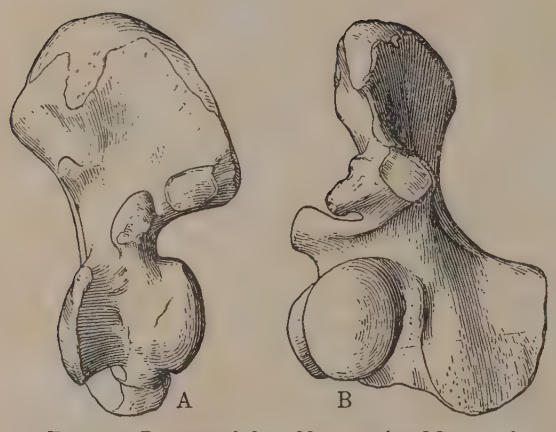

FIG. 31.—*E. megacephalus.* No. 4255 Am. Mus. × ⅔.
A. Posterior edge of right humerus.
B. Anterior view.

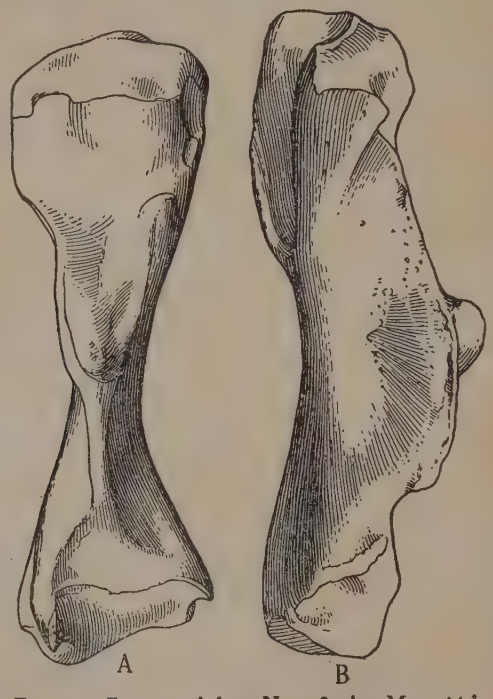

FIG. 32.—*E. megacephalus.* No. 4183 Am. Mus. × ⅓.
A. Posterior view of left femur.
B. Lateral view of same.

The humerus (No. 4186 Am. Mus.): The proximal and distal ends are almost at right angles. The articular face on the proximal end is carried around the end somewhat obliquely, as in the Pelycosaurs. The short shaft between the two ends is nearly quadrangular in section, due to strong ridges from the edges of the distal and proximal ends. On the upper part of the anterior edge there is a strong, thick process expanded at right angles to the main axis of the bone; this is one of the most characteristic features of the *Eryops* humerus; it is not developed in any reptilian bone except a humerus, No. 6541 University of Chicago, from Vermilion County, Illinois, described by Williston as *Desmospondylus anomalus*. On the outer side of

the shaft, when the head is set with its greatest diameter vertical, as is the case when the foot is advanced, is a strong, ectepicondylar process, standing directly out from the bone. On the upper (posterior) side is a third heavy process at the lower end, flat above and continuous with the shaft; below this the process is convex from side to side and convex anteroposteriorly; its lower face is continuous with the lower surface of the bone. Opposite this process and entirely on the anterior face of the bone, is the hemispherical surface for the head of the radius. The face for the ulna is confined to the distal end of the bone. The entepicondylar process is of good size, and resembles that of *Diadectes* in the nearly straight, inner edge. There is, of course, no entepicondylar foramen.

The *ulna* has the shaft sharply bent outward; the proximal end is expanded with a shallow, concave face. The olecranon process is short and blunt, and there is no deep concavity to receive the end of the humerus, as on the reptiles. The shaft is triangular in section; the lower end has two facets set at a sharp angle to each other.

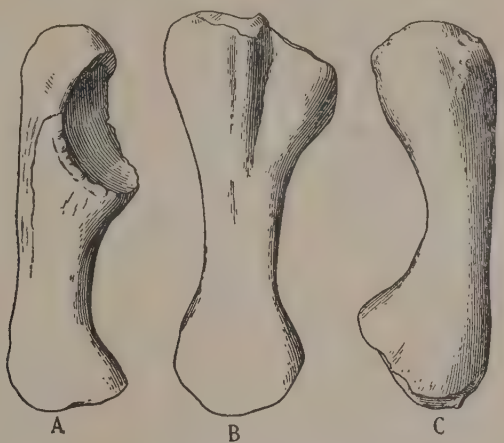

FIG. 33.—*E. megacephalus*. No. 4893 Am. Mus. × ½.

A. Ulna of right side.
B. Anterior view of right tibia.
C. Fibula of left side.

The *radius* has the proximal end expanded, with a shallow cup for the hemispherical process of the humerus. The lower end is widely expanded and divided into two faces; one, on the outer side, looks almost directly distally; the other is inclined sharply upward, and looks toward the ulnar side. These faces hardly show on the upper surface, where the distal edge of the bone appears as an unbroken curve.

The *carpus* (specimen No. 4186 Am. Mus.) contains eleven bones. They are practically in position, but a little disturbance leaves some room for difference of opinion as to their exact interpretation. There are four bones in the proximal row in contact with the radius and ulna; the two outer in contact with the radius, the third with both radius and ulna, and the inner with the ulna. The element in contact with the radius and ulna together appears as if it might possibly be two bones closely pushed together in fossilization, but it is more likely that it is a single element. There are

two elements in the middle of the carpus, a large cubical bone on the outer side and a smaller on the inner. There are four bones in the distal row connected with the metacarpals. The four bones in the proximal row may be radiale, two intermedia, and fibulare, or they may be radiale, intermedium, fibulare, and pisiform. The figures give the general form and relations.

The *metacarpals* preserved are short and stout and the phalanges are of similar form. Whole foot short and broad, with wide terminal phalanges.

The pelvis and posterior limb (Nos. 4183, 4582 Am. Mus., plate 9): The pelvis is peculiarly frog-like in its general suggestion; the bones of each side are closely united, and the acetabulum is closed. The ilium is elongate and nearly straight, and the ischium and pubis are united by a wide and strong symphysis. The *ilium* has the upper part prolonged into a narrow blade with nearly parallel edges; the upper end is slightly thickened; on the posterior edge, near the lower end, is a slight notch. In one specimen, No. 4183 Am. Mus., there are a few rugose pits at the point of attachment of the sacral rib, but this is not noticed in other specimens. The *pubis* has the anterior face thickened and widened, so that when the two bones of opposite sides are joined there is a broad, flat surface facing anteriorly. This reaches as far up as the center of the acetabulum. The pubic foramen is situated far forward, just below the anterior edge of the acetabulum, and emerges on the flat anterior face. The *ischium* is broad and thin, and projects posteriorly beyond the ilium. The pubis and ischium stand nearly vertical, and the symphysis is very narrow on the bottom line, not over 1 or 2 cm., but is very wide vertically at the anterior end and narrower posteriorly. The relation of the sacral rib, shown in three specimens, demonstrates that the pelvis touched the ground only at the anterior corner of the pubis; the outer, lower, edge of the symphysis is nearly straight, and in the natural position of the pelvis was inclined upward and backward, but the inner, upper edge is nearly parallel to the ground. This is the result of the symphysis being so much broader at the anterior end. Because the pubis and ischium are so nearly vertical, the aperture of the pelvis is very narrow. The acetabulum is broad and very shallow, with slightly raised edges. This is most prominent at the antero-inferior end, just over the pubic foramen.

The *femur* (4193 Am. Mus.) is nearly straight with prominent, expanded extremities. The proximal end is thickened on the inner side, round behind and flattened anteriorly, but it lacks the deep concavity of the anterior face present in the Pelycosaurs. The two edges of this flat face extend straight downward for a few centimeters, and then converge and unite to form a high, thin ridge with a convex edge, which extends to the articular face of the distal end. The section of the middle part of the shaft is a sharp isosceles triangle with the apex forward; this ridge is one of the most characteristic features of the *Eryops* femur and renders it unmistakable. The distal face is partially divided by a deep groove, the outer portion being much more prominent than the inner.

The tibia (No. 4893 Am. Mus.): The upper end is expanded and very imperfectly divided into two faces by a notch on the anterior border. The whole surface is inclined slightly inwards. The shaft is suddenly contracted below the head and has a triangular section. The lower end of the bone is turned inwards, so that the lower face lies at an angle of about 45° to the upper. This face is not divided into facets, but it is semicircular in form, to permit it to articulate with more than one bone.

The fibula (No. 4893 Am. Mus.): This bone is very flat fore and aft, perhaps in some measure due to the crushing of the specimen. The upper end was probably concave toward the tibia, and partially embraces it as in *Labidosaurus*. The lower end is expanded, and the articular face is steeply inclined toward the tibial side.

The foot: The tarsus described by Cope can not be made out with any assurance. It is certain that many of the elements described by him can not be the bones he considered them, but the condition of the specimen does not warrant any conclusions. It seems best to leave this until better material can be found. The tarsal and foot bones are all heavy and stout, and indicate a broad, wide foot, notably larger than that of the fore limit.

The following figures, in addition to those in the original description, give some idea of the absolute size and proportions of the genus:

	MM
Largest skull No. 4186 Am. Mus.:	
Length on mid line	443
Total length	523
Breadth at quadrate region	463
Another skull No. 4180 Am. Mus.:	
Length on mid line	368
Total length	449
Breadth at quadrate region (corrected for crushing)	300
A large pelvis No. 4852 Am. Mus.:	
Length of symphysis	278
Symphysis to crest of ilium	327
Another specimen No. 4183 Am. Mus.:	
Length of symphysis of pelvis	234
Symphysis to crest of ilium	250
Length of femur	200
Restored specimen No. 4893 Am. Mus.:	MM
Length of symphysis of pelvis	212
Symphysis to crest of ilium	225
Length of scapula	312
Length of femur	175
Length of humerus	150
Length of tibia	121
Scapula No. 4037 Am. Mus.:	
Extreme length	384
Breadth of scapula and cleithrum at distal end	128
Breadth of scapula at proximal end (estimated)	160

RESTORATION. (Plates 9 and 10.)

Specimen No. 4893 Am. Mus. is a skeleton so nearly complete that it makes it possible to restore the creature with some degree of confidence. The skeleton was found but slightly disturbed in the ground, but unfortunately the vertebral column was broken, so that the exact position of the dorsal vertebræ is a little in doubt. The feet and a few of the caudal vertebræ are missing, and the skull is pretty badly broken and many parts are lost. Fortunately a lower jaw is preserved entire and this gives the length. A skull of the proper length, found in the collection, was used in completing the restoration and the fore feet are restored from specimen No. 4186. The hind feet are restored almost entirely, and it is not at all certain that they are correct.

The peculiar position of the pelvis gives the animal a striking resemblance to some of the restorations of *Labyrinthodon* published years ago, for the hind quarters are high and the back slopes gently downward, nearly in a straight line to the skull, which lay flat on the ground, in the resting attitude. The limbs were short but stout, and far from inefficient in driving the creature through the water; it is uncertain whether the digits bore claws or not. The tail was short and of no use in propulsion. The barrel was round and heavy, but not so much so as to give the animal an obese appearance. The sketch model, shown in plate 10, which is in true proportion, shows that the body was rather slender, and there is a suggestion of some

activity. The habits of the creature can hardly be in doubt. The superior position of eyes and nostrils shows that it lay nearly submerged until some prey came within reach, when a sudden rush with its very capacious mouth extended ended in the engulfment of the prey. The coprolites show remains of fish and amphibian bones (Neumeyer, 63).

Parioxys ferricolus and Anisodex imbricarius Cope.

So little is known of these forms that the discussion of their morphology must await future discoveries.

Genus ACHELOMA Cope.

Acheloma cumminsi Cope (page 34). (Plate 11.)

Characteristic specimen: The type No. 4205 Am. Mus.

The original description of this genus and species is good; a few points are added. The skull is incomplete, and there is considerable plaster in the facial and postorbital regions, where vacuities occur in *Trematops* Williston, which the skull resembles in many respects; but the two are distinct. The skull is higher in the cranial region than *Eryops*, and there is a decided preorbital contraction. The sutures can not be made out.

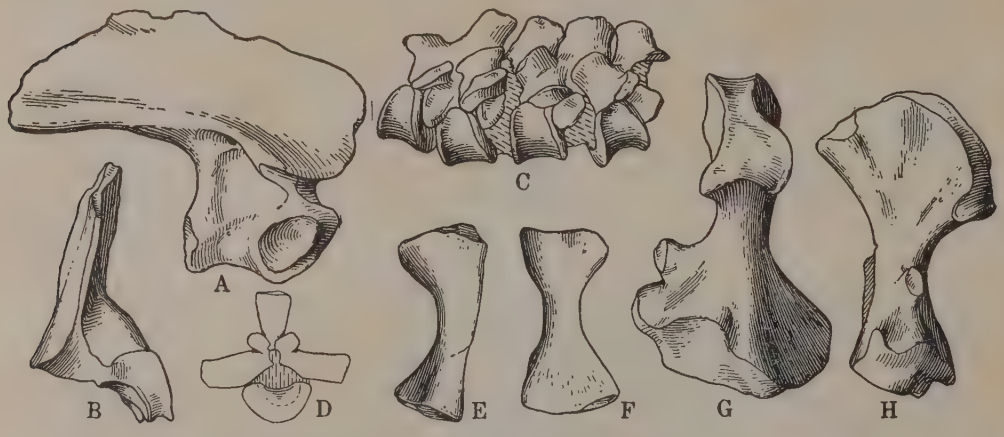

Fig. 34.—*Acheloma cumminsi.* No. 4205 Am. Mus. × ¾.

A. Lateral view of right scapula.
B. Anterior view of same.
C. Lateral view of four dorsal vertebræ.
D. Diagrammatic anterior view of a dorsal vertebra.
E. Ulna.
F. Radius.
G. Anterior view of right humerus.
H. Posterior edge of same.

The *scapula* presents a most remarkable appearance, which attracted Cope's attention (see original description). In the present position of the scapulæ, which is evidently a little too high, the blade is set at an angle of 45° to the vertical and overlies the back; the coracoid portion is also at an angle of 45° from the vertical, so that the two parts of the scapula are at right angles to each other (see fig. 34, A and B). The blade is elongate and rather wide; the posterior end is thick and shows extensive cartilaginous attachment. The upper edge is thin and the lower thick and rounded. From a point near the middle of the lower edge, a process runs directly inward to support the coracoid portion, which lies at right angles to the scapulæ (see fig. 35 B). The lower edge is continued forward on the outer surface of

the bone, as in *Eryops*, and ends in a prominence over the cotylus. Just beneath this prominence, the bone is penetrated by a large foramen. Beneath the prominence formed by the continuation of the inner edge lies the humeral cotylus, but it is very different from that of related *Amphibia*. Below

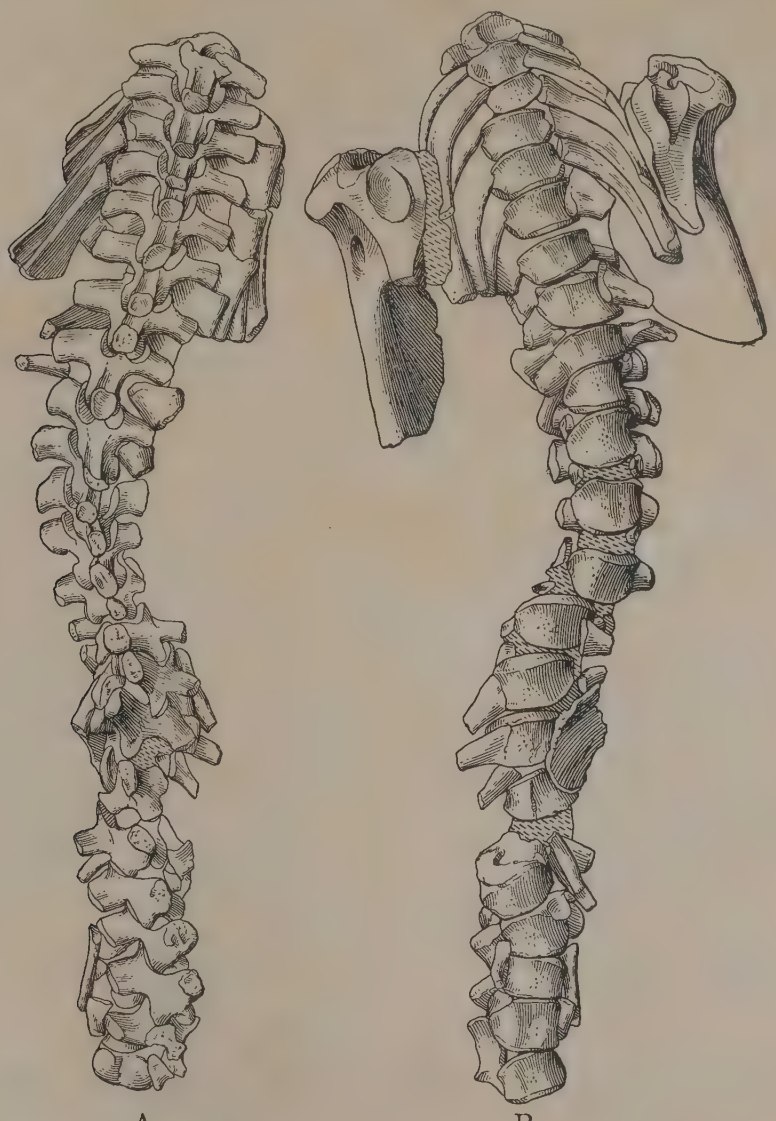

FIG. 35.—*Acheloma cumminsi*. No. 4205 Am. Mus. × ⅔.
A. Dorsal view of vertebræ column without scapulæ.
B. Ventral view of same, scapulæ in position.

the prominence is the flat face of the coracoid portion, and near the anterior edge is a shallow depression, slightly oval in outline. There is no well-formed cotylus, and the head of the humerus can not be made to fit into the shallow pit or in any other part of this region.

The *ribs* are single-headed and quite flat, with expanded distal and proximal ends. They overlapped each other from before backwards, forming a strong protection for the thorax.

Abdominal ribs were present as narrow rod-like elements, resembling those of *Labidosaurus*.

There are twenty-two *vertebræ* in series and one attached to the skull; the series is, therefore, not continuous with the skull and it ends anterior to the sacrum. The spines are low and stout with a round or oval terminal face, showing attachment to a cartilaginous or bony plate. The neurocentra carry transverse processes, which are rather longer in the cervical and thoracic regions than posteriorly; the ends of the processes are elongate and inclined downward and forward toward the intercentra, but do not reach them. The zygopophyses are oblique. The pleurocentra are small and the intercentra without any notch on the posterior edge, as in *Eryops*. In the same region the rib-heads are nearly twice as long as the faces on the transverse processes, and must have reached to the intercentra, but were attached to it by cartilage. In the posterior dorsals, the face on the transverse process extends downward and forward to the intercentrum, but the rib does not seem to touch the intercentrum. The posterior zygapophyses are more nearly horizontal and the whole vertebra longer. The lower surface of the intercentra shows a reticulate sculpture, somewhat similar to that of *Diplocaulus*. The edges of the zygapophyses are particularly prominent, forming a well-marked line on the sides of the neurocentra; this is one of the striking features of the specimen as a whole.

The *humerus* is a miniature of that of *Eryops*, except that it lacks the articular condyles. The two ends stand at an angle of 70° to 75° to each other. The surfaces are flat and indicate the presence of a considerable quantity of cartilage. The outer edge of the upper face is expanded transversely like the head of a capital T; this corresponds to the prominent, transverse process in the same position in the head of *Eryops*. The shaft is much more slender than in *Eryops*, but there are similar processes on the lower end. In correlation with the lack of condylar surfaces, there is no well-developed head for the radius. The entepicondylar process is proportionately as strong as *Eryops*, but the distal surface extends to its inner extremity. The humerus of the right side has a perforation in the position of the entepicondylar foramen, but there is none in the left side. This opening has been interpreted as an entepicondylar foramen, but in the opinion of Doctors Broom and Williston and the author it is an accidental perforation, probably produced after death.

The *radius* has a narrow, straight shaft with the two ends considerably expanded.

The *ulna* is slender and curved, with the upper end expanded, but nearly straight, and not curved as in the reptiles. There is no olecranon process.

The measurements are given in the original description.

Genus TRIMERORHACHIS Cope (page 39).

Characteristic specimens: Nos. 4565, 4557, 4714, 4584, two specimens, Am. Mus.

The following description is drawn from several specimens. The skull is rather elongate in the cranial region and very flat. The elongation is

shared by all the postorbital bones, no horns or processes being developed. The otic notches are very slightly developed, but the quadrate region extends quite a little posterior to the occipital condyle. The sutures of the skull are known only imperfectly; in specimen No. 4557 the sutures can be made out as far as shown in fig. 36 B. The orbits are relatively small and nearly circular, and are situated in the anterior third of the skull. They are, with the nares, entirely superior in position. The nares are not terminal. On

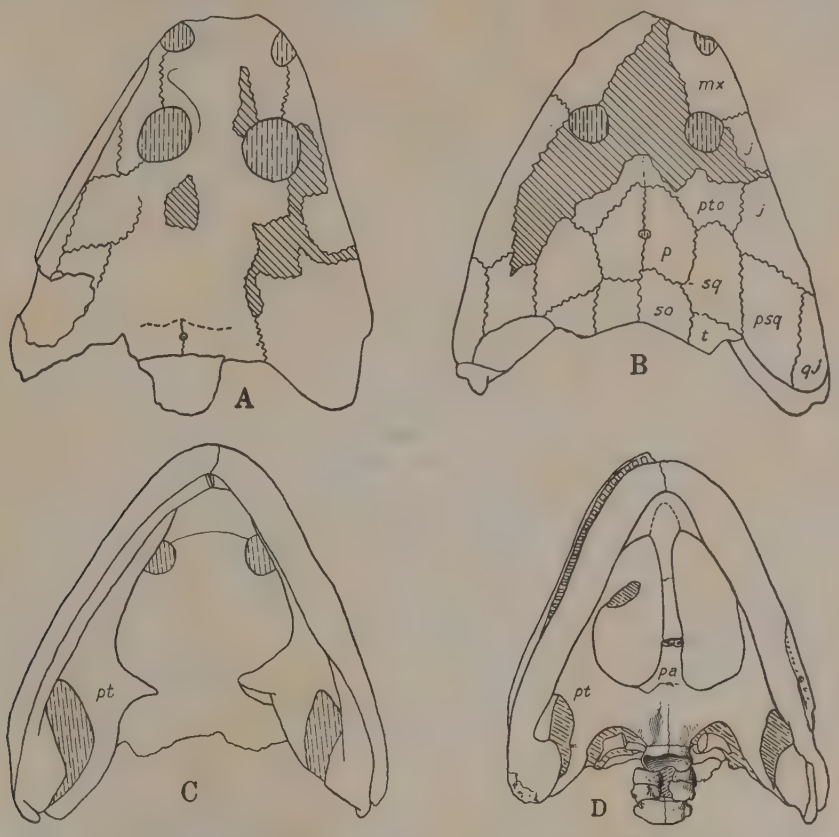

FIG. 36.—*Trimerorhachis insignis*. No. 4557 Am. Mus.

A. Top view of a skull. × ⅛.
B. Another skull carrying same number as that shown in A, showing such sutures as can be made out. × ⅛. Lettering as usual.
C. Lower view of same skull shown in B. × ⅛. *pt*, pterygoid.
D. Lower surface of skull shown in A. × ½. *pt*, pterygoid; *pa*, parasphenoid.

the lower surface the elongate parasphenoid joins a well-formed basioccipital, which bears a single, oval occipital condyle with a concave, articular face. The pterygoids send processes inwards to join the parasphenoid, and backward to the quadrate region. The anterior processes of the pterygoid are very narrow, with concave inner edges, leaving very large palatal vacuities. The posterior portion of parasphenoid and the pterygoids are covered with fine teeth.

In two specimens, considered by Cope as *T. insignis*, there is considerable difference in the parasphenoid and basioccipital bones. In No. 4565,

the type, the sides of the posterior part of the parasphenoid are much more sharply cut out and the whole region is narrowed; the section of the occipital condyle is broadly heart-shaped. In No. 4557 the same region is much broader, and the section of the occipital condyle is a wide oval. It is possible that these should be reckoned as distinct species, but it seems best to wait for more evidence.

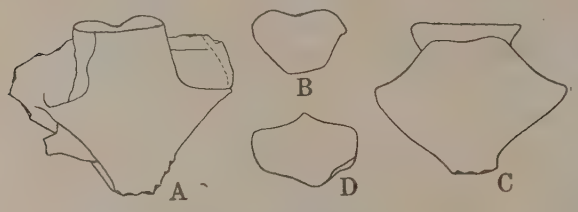

FIG. 37.—*T. insignis.*

A. Outline of base of skull. No. 4565 Am. Mus. × ⅔.
B. Cross-section of occipital condyle of same.
C. Outline of base of skull. No. 4557 Am. Mus. × ⅔.
D. Cross-section of occipital condyle of same.

It is impossible to make out the sutures between the bones in the anterior part of the palate. The internal nares are far forward, and the palatine and prevomerine regions are covered with small teeth; there are no tusks visible.

The *lower jaws* are widely separated posteriorly, due to the width of the skull; they curve forward and inward and meet in a narrow symphysis. The outer surface of the jaw is covered with a beautiful sculpture, which is particularly heavy over the posterior surface and radiates from a point near the lower edge (plate 12, fig. 4). The articular surface is as described by Cope. Just anterior to the articular region, on the inner side, there is a wide opening into the Meckelian cavity; there seem to be no anterior openings of this cavity, but two small foramina penetrate the jaw, one just below the articular surface near the posterior end, and another directly below the anterior end of the Meckelian opening. The sutures which have been made out are shown in fig. 38. There is a single series of irregular teeth on the edge of the jaw, except just anterior to the opening of the Meckelian cavity, where there is an oval patch of small, sharp teeth, about 3 cm. long, inside the regular series and separated from it by a deep groove. The anterior tooth is somewhat larger than the others. A large pit on the inner surface, about 2 cm. from the anterior end, indicates the presence of a tusk on the palatine.

FIG. 38.—*T. insignis.* Inner view of right lower jaw. No. 4714 Am. Mus. × ⅔.

The *vertebræ* are in general as described by Cope. The prominent characteristic is the divided or weakly united condition of the two halves of the neural spine.

The *first vertebra* has a form similar to that of *Eryops;* the neural arch is divided into two halves, each terminating in a sharp spine. These spines are inclined backward and lie on either side of the enlarged spine of the second vertebræ. A small, button-like process lies on the anterior surface of each half just opposite the neural canal, and probably served for con-

nection with a rudimentary vertebra, anterior to the first, or with the skull. The posterior zygapophyses are of good size. There is a small intercentrum.

The *second vertebra* has a large, double spine, showing indications that the two halves were never firmly united. The posterior edge is broad, the anterior thin, and extending far forward between the halves of the spine of the first vertebra. There is, proportionately, a very large intercentrum in this vertebra. A facet on the posterior edge of the intercentrum and on the anterior edge of the pleurocentrum, with one on the lower edge of the pleurocentrum, form a face for the attachment of the rib.

FIG. 39.—*T. insignis*. No. 4565 Am. Mus. × ¾.
A. First two vertebræ. From right side.
B. Four dorsal vertebræ from right side, showing intercentra and pleurocentra.
C. Neural spines of three dorsal vertebræ, showing permanent separation of two halves.

In specimen No. 4557 Am. Mus., the intercentra of the first three vertebræ are divided on the mid line; the halves of the first two are widely separated; in the third they are distinct but still in contact. There seems to be no doubt that this is a true division and not an accidental break (fig. 36 D). Distinct lateral processes are visible on the first two, probably the edges of the facets described above. The separate condition of the anterior intercentra is probably a survival of the primitive, phylospondylus condition. No trace of such a condition is known in other forms, but it must be remembered that the anterior vertebræ are not well known in any other form, and even in *Eryops* the first intercentrum is missing. In the more posterior vertebræ the spines are distinctly split and have a concave upper end and anterior margin, indicating the presence of a large amount of cartilage. The spines are inclined sharply to the rear, each overlapping the succeeding vertebra. The anterior zygapophyses are well formed, but the posterior are represented by faces on the sides of the neural spine near the base. The intercentra show distinct faces on the posterior edge, which, in combination with the similar faces on the anterior edges of the pleurocentra, form facets for the rib head. The pleurocentra are relatively small. The intercentra form nearly half a circle and are very thin, so that the notochord is not contracted.

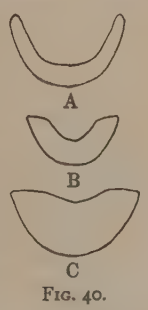

FIG. 40.

Trimerorhachis is the most primitive of the amphibia from Texas in this regard. Figure 40 shows the condition of intercentra in three forms in cross-section. That of *Trimerorhachis* (A) is little more than a thin section of a tubular wall around the notochord; in *Eryops* (?) *reticulatus* (B) the wall of the intercentrum is much thickened and the notochord was greatly contracted; in *Eryops megacephalus* (C) the intercentrum is practically a wedge, with a convex lower surface and a very small notch on the upper, sharp edge; the notochord must have been very nearly completely interrupted in many vertebræ in *Eryops*, though it was widely expanded intervertebrally. The lower surfaces of the intercentra are characteristi-

cally pitted and marked with a reticulate sculpture. The sacral and caudal vertebræ are unknown.

The *ribs* of the anterior and middorsal region have heavy, single-headed, proximal ends; the body of the rib is short and the distal half is expanded into a thin blade.

The *shoulder girdle* is known only from the clavicles and interclavicle. The interclavicle, No. 4717 Am. Mus. (plate 12, fig. 2), is a thin rhomboidal plate, with one angle posterior, but not drawn out to a point. The converging posterior edges are thickened and the sculpture is carried out to the edge, making it somewhat rough. The anterior edges are thin where they were overlapped by the clavicles. The sculpture radiates, in a general way, from a point somewhat posterior to the middle of the median line.

In the bone beds, where the scattered bones of *Trimerorhachis* occur abundantly, mingled with remains of other creatures, a peculiarly formed plate is of very frequent occurrence; one such is shown in fig. 41 B.

A similar plate is associated with one of Cope's specimens of *Trimerorhachis* and in specimen No. 4866 Amer. Mus., such a plate lies between the lower jaws. It is uncertain whether these are the clavicles or whether they are protective plates normally gular in position. One edge is nearly straight; from this the plate rises in a convex surface and contracts to an apex, which is curved toward the underside of the bone; the whole plate is marked by a sculpture of lines radiating from the apex.

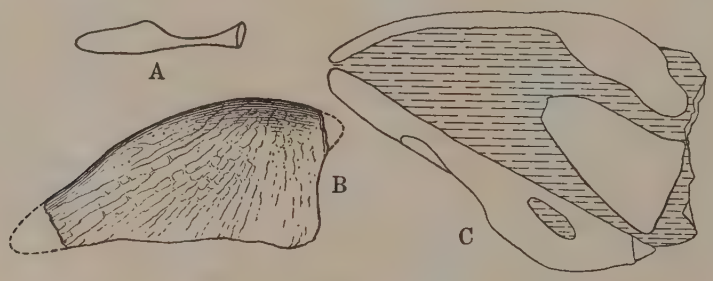

FIG. 41.

A. *T. insignis.* Outline of a rib, showing posterior expansion of blade. No. 4675 Am. Mus. × ¾.
B. *Trimerorhachis* sp. Outer view of a plate found in the thoracic or gular region. No 125 (Field No.) Am. Mus. × ½.
C. *Trimerorhachis* sp. Lower view of a small skull, showing such a plate as is figured in B, in position as found. No. 4866 Am. Mus. × ¾.

Under the No. 4720 Am. Mus. are collected three *humeri* closely similar to a less perfect one associated with a skull of *Trimerorhachis*. The ends are turned at an angle of 45° to each other, hardly half as great as in *Eryops* and *Diadectes*.

The articular surfaces are hollow and imperfectly ossified, showing the presence of a large amount of cartilage. The inner side of the proximal end is wider than the outer and the face descends somewhat on the side of the bone; the shaft narrows to a triangular section. The outer edge of this part is interrupted by a stout rugosity, flattened or concave on the surface and not standing out from the bone; it is the homologue of the stout transverse process in the same position on the humerus of *Eryops*. On the anterior angle there is a slight tuberosity just above where the head narrows to the

shaft. The lower end is wide, but very thin. The entepicondylar process is proportionately wide; the outer part of the distal face is thickened and bifurcated, giving it a U-shaped section, the arms of the U being the terminations of narrow ridges from the shaft. There are no faces for radius or ulna.

A *femur*, No. 4584 Am. Mus., in all probability belonging to *Trimerorhachis*, has the two ends oval and nearly parallel. The shaft is narrow and rounded. On the posterior surface, near the proximal end, is a strong rugose process with the end cupped like the ends of the bone, showing cartilaginous attachment. The lower end of the process is continued as a thin ridge, which narrows to a line running nearly to the distal end of the bone. The lower face of the femur is roughly divided by a constriction near the middle. The outer part is wider than the inner, but there are no distinct faces for tibia and fibula.

Another femur (bearing the same number) is of a slightly different form. The upper and lower ends are parallel, but the process on the posterior face is not separate from the bone; it is continuously attached to it and its upper face is a part of the proximal face of the bone. The end is similar to the first described.

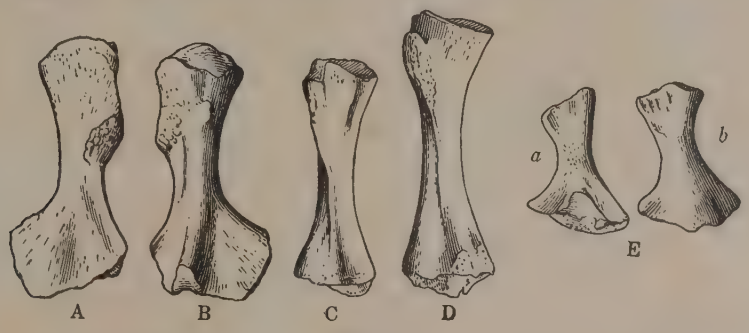

FIG. 42.

A. *Trimerorhachis* sp. No. 4720 Am. Mus. × ⅔. Humerus of right side, posterior view.
B. Same humerus, anterior view.
C. *Trimerorhachis* (?) sp. No. 4584 Am. Mus. × ⅔. Small femur probably belonging to *Trimerorhachis*.
D. A second, larger femur.
E. *Trimerorhachis* (?) sp. × ⅔. A small ilium in the collection of the American Museum belonging to *Trimerorhachis* or possibly to *Zatrachys*. *a*, from outer side; *b*, from inner side.

Certain small *ilia* found in the bone beds belong either to *Trimerorhachis* or *Zatrachys;* it is probable that there was little difference in the axial skeletons of these forms. The upper end of the ilium is thick and expanded in fan shape; the inner surface is marked with radiating lines, the outer face concave. The shaft is rather elongate and slender. The lower end is expanded to take part in a good-sized cotylus. The three bones of the pelvis were apparently strongly united.

Trimerorhachis is not yet sufficiently well known to attempt a restoration or a description of its probable habits. The extremely large notochordal space left between the elements of the vertebræ and the phyllospondylous condition of the anterior vertebræ proclaim it as the most primitive form of Amphibia from Texas.

Measurements.

Skull No. 4570 Am. Mus. Nat. Hist.:	mm
Length on mid line	122
Length to posterior end of lower jaw	139
Greatest breadth	141.5
Distance from back of skull to middle of orbits	76
No. 4714 Am. Mus Nat. Hist.:	
Length of lower jaw	180
Greatest depth of ramus	31.5

Three humeri No. 4720.	No. 1.	No. 2.	No. 3
Length	49	46	45.5
Width distal end	23	21.5	21.5
Width proximal end	15	15	15

A femur, No. 4584 Am. Mus. Nat. Hist.:	mm
Length	50
Breadth proximal end	16.5
Breadth distal end	17
A second femur, same number:	
Length	43
Breadth of distal end	14
Breadth of proximal end	12.5
Ilia:	
Length of an average specimen	37
Breadth of lower end	19
Breadth of lower end	13

Trimerorhachis insignis Cope.

The morphological description of this species is contained in that of the genus.

Trimerorhachis conangulus Cope. (Plate 5, fig. 6.)

Characteristic specimen: Type No. 4569 Am. Mus. Nat. Hist. Cope Coll.

There is some doubt whether this creature should be retained in the genus, but it is better to leave it there until further knowledge is gained. It is known from the skull only, and was identified by Cope as *Trimerorhachis* by the anterior position of the orbits and the united condyles.

The original description is adequate. It is to be noted that an intertemporal is clearly shown on both sides (fig. 8). As the sutures of the skull in the typical specimens of the genus can not be made out clearly, it is impossible to say whether this is a constant feature.

Trimerorhachis mesops Cope (page 46). (Plate 12, fig. 1.)

Characteristic specimens: Type No. 4568 Am. Mus. Nat. Hist. Cope Coll.

The original description points out the characters by which this species may be distinguished from the other species of the genus. The specimen is so imperfect that it does not permit of an accurate characterization. The peculiar "sheet of matrix," mentioned by Cope, is the most interesting part of the specimen. This is a wrinkled sheet composed of numerous alternate red and white layers, not over one-tenth of a millimeter thick. The white layers are badly contorted and seem to be discontinuous; an attempt to trace them for any distance fails. The layer is also apparently made up of small, broken fragments, as if it had been originally a heavily calcified tissue, sufficiently so to be brittle under pressure. A small fragment, ground thin and placed under the compound microscope, was declared by Dr. Huber, professor of histology in the University of Michigan, to present an appearance in some places like that of epithelial cells, such as occur in horny parts of the epidermis. It is possible that this animal possessed a unique ventral armor made up of successive layers of heavy epidermis; this is rendered more probable by the fact that no trace of the characteristic scutes or rods, which form the abdominal protection of contemporary amphibians, is found in the specimen. If the creature died and sank down upon some fragment of skin from some other creature, the abdominal ribs would have been preserved, but none are present. The plate of matrix is unique, and future discoveries must determine whether it is an accidental association or a peculiar feature of this animal.

Genus ZATRACHYS Cope (page 47).

Characteristic specimens: Nos. 4586, 4587, 4589 Am. Mus. Nat. Hist. Cope Coll.

The genus is known only from the skull, and but a single species, *Z. serratus*, is identifiable. Cope, in 1884 (1, 18), remarked of this genus: "Rugosities project in the form of teeth along the external alveolar border. Individuals with sculptured neural spines and dermal bones are referred here." This is right with regard to the serrated edges of the skull, but there is no warrant for associating the forms having sculptured and expanded neural spines, such as *Z. apicalis* Cope, with the skulls called *Z. serratus* and *Z. micropthalmus;* the expanded and sculptured spines are associated, in *Aspidosaurus*, with a skull like *Trimerorhachis*.

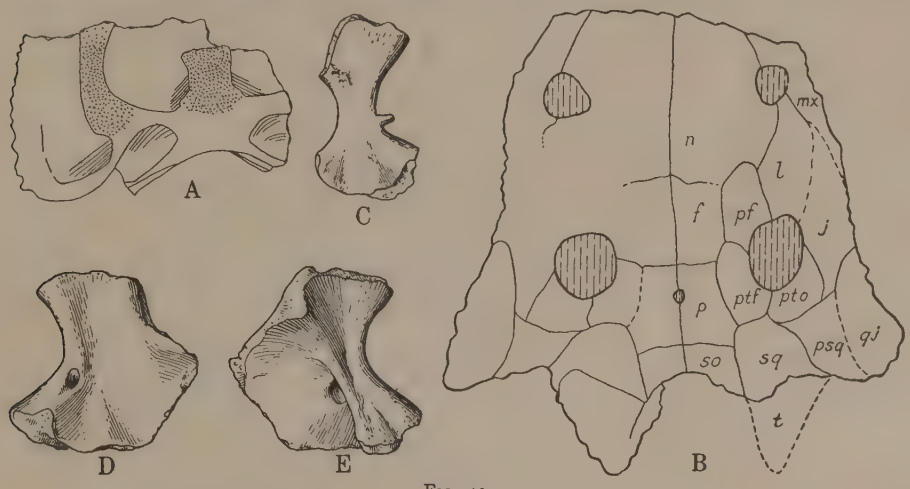

FIG. 43.

A. *Z. serratus*. Lower view of posterior portion of skull, showing fine teeth on parasphenoid and pterygoid. No. 4589 Am. Mus.
B. Same No. 4587 Am. Mus. × ⅓. Diagram of skull, showing sutures. Lettering as usual.
C. *Zatrachys* sp. No. 4584 Am. Mus. × ¾. Posterior view of humerus of left side.
D. *Zatrachys* sp. No. 4560 Am. Mus. × ¾. Right scapula from outer side.
E. Same from inner side.

The type specimens were described by Cope without having been cleaned; a little care has removed most of the matrix from two of the skulls and it is possible to give a more accurate account of them. They are longer than wide and very flat in the facial region; the orbital and post-orbital portion is more elevated. The posterior edge of the skull and the sides, as far forward as the nares, are ornamented by sharp, thin projections, which are larger and more prominent posteriorly. Probably associated with this specialization is the peculiar character of the sutures. The surface of the bones has been largely destroyed, but enough remains to show that there was a reticulate sculpture and a strong radial structure; the edges of the bones are drawn out into fine points, closely interlocking with the edges of neighboring bones and forming a very complicated suture. The appearance is strikingly like that in many fishes.

The region anterior to the orbits is very flat; two ridges run forward from the orbits, separating this depressed area from a more elevated one on either side. The orbits are on the elevated portion of the skull and sur-

rounded by elevated ridges. Just anterior to the orbit is a deep depression, not a fenestra; the posterior and inner sides are nearly vertical, but the outer parts open gently on the sloping surface of the skull, and extend to the narial opening anteriorly.

The *nares* are located far back and look almost directly upward. They are separated from the depression behind by a slight ridge and from the depression of the median region of the skull by the extension of the longitudinal ridge described, which does not, however, reach to the anterior end of the skull. From the nares forward the surface of the skull is perfectly flat and a little lower than the edge; this depressed area joins that of the median facial region anteriorly. A strong ridge passes from orbit to orbit, not terminating the facial depression, as described by Cope, but separating it from a similar, but less pronounced depression behind, in which lies the parietal foramen. The sides of the temporal region slant steeply outward and downward (see fig. 8, A and B).

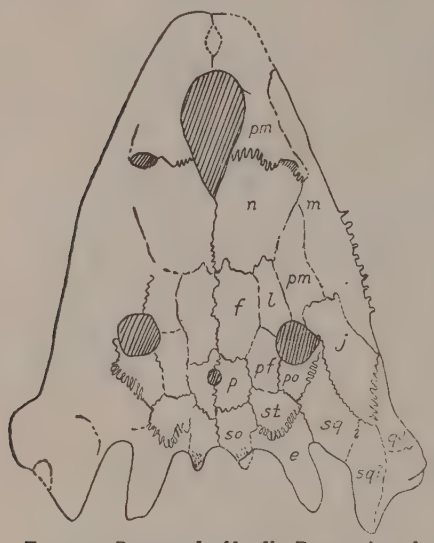

FIG. 44.—*Dasyceps bucklandi*. Restoration of skull from von Huene. × ¼.

The *maxillary* bone is very slender, but its posterior termination can not be made out. The teeth are small and conical, and no palatine tusks can be made out in the specimens, though they may have been present. The edges of the maxillary extend straight out beyond the tooth line, like the overhanging eaves of a roof.

The *quadrate* is not determinable; it may have been a small element concealed by the surrounding bones, as in *Eryops*. The articular region of the lower jaw fits into a deep depression of the skull. The surface of the parasphenoid and pterygoids exposed is covered with minute teeth.

The position and relations of the bones determined are shown in fig. 43 B.

A small scapula associated with bones of *Zatrachys* probably belongs to the genus. The form is shown in fig. 43 D and E.

Von Huene has recently redescribed the skull of *Dasyceps bucklandi* Lloyd, from the Permian of Kenilworth in England (55). A comparison of fig. 44, reproduced from v. Huene's paper, with figs. 8 B and 43 B shows how great a similarity exists between the two forms. The genus *Dasyceps* seems to lack the deep pits between the orbits and the nares, and *Zatrachys* does not have the median opening between the nares, but in other respects the skulls are almost identical. It is apparent that both genera are highly specialized members of groups which had advanced far in the peculiar development of excrescences and ornamentation characteristic of the Permian or upper Carboniferous. It is perhaps not justifiable to place these forms in a common family, but the separation can not be very great.

A larger skull than any described by Cope (No. 4873 Am. Mus. Nat. Hist.) is probably a *Zatrachys*, but is covered with a hard, refractory matrix. Total length on mid line, 137 mm.

A small humerus, of different form from that of *Trimerorhachis*, is provisionally referred to *Zatrachys*. The two ends are nearly parallel. The proximal articular ends are deeply excavated and without condyles. The proximal face descends a considerable distance on the inner edge of the bone. There is little resemblance between this humerus and that of *Eryops*. The only process on the shaft is a slender ectepicondylar process, and the entepicondylar process is not large. The humerus is 41 mm. long.

Genus DISSOROPHUS. (Plate 13.)

Dissorophus multicinctus Cope.

Characteristic Specimens: Nos. 4593 and 4343 Am. Mus. Nat. Hist. Cope Coll. and No. 648 University of Chicago.

It has been shown in the systematic revision that *Otocœlus* is indistinguishable from *Dissorophus*. The condition of the skull is very poor, but enough can be made out to show that it has complete temporal fenestræ crossed by a slender plate or bar of bone dividing it into two halves. This character was made out by the author in the type skull. Later discoveries by Williston (73), in the summer of 1909, have confirmed this character and have added much to our knowledge of the skull and carapace. The following description is largely drawn from Williston's description, but there is some additional matter and some corrections.

The *skull:* "The skull is very broad posteriorly, with a rounded, obtuse muzzle. The orbits are situated about midway in its length; they are rather small, nearly circular in outline, and broadly separated. The table of the cranium, back of the orbits, is rather broader than long, a little wider anteriorly, with a broad emargination behind; it is nearly plane, with its margins elevated. The parietal foramen is situated a little back of a line drawn through the posterior margin of the orbits. Just back of each orbit there is a distinct depression, as in *Cacops*, apparently for the lodgment of some gland. In the middle part behind there is, on each side, a prominent, nearly hemispherical elevation, deeply impressed with large pits; they correspond to the prominent rugosities of the *Cacops* skull, but are much more rounded and less angular. Behind, these swellings are partly separated by an angular emargination of the hind border. The epiotic region on each side is produced backward considerably beyond the transverse line of the rounded swellings. The broad surface between the orbits is shallowly concave transversely. The thickened upper margin of the orbits is nearly horizontal to the middle of the orbit in front, where there is a rugosity, the outer border of which is nearly vertical. The face in front of the orbits is convex, with a depression on each side in front of the orbital rugosity. The nares are large, oval in outline, and are directed upward and outward and forward. Below and a little behind the orbits there is a distinct elevation or rugosity. The posterior lateral or temporal region is unfortunately wanting on each side, or rather the parts were so mutilated that they could not be joined. The structure here is quite surely, as in *Cacops*, the epiotic prolongation with its attached quadrate inclosing the ear opening at the bottom of a cavity. The upper margin of this opening is preserved in part on the left side, as is also most of the smooth bone forming the anterior part of the auditory cavity, the ridge limiting this surface from the roughened exterior of the side of the skull in front of it running downward and backward from a point about 10 mm. back of the orbital margin, to the jugal border.

"On the palatal side of the skull the basioccipital, basisphenoid, and parasphenoid could not be recovered, nor the vomerine portion in front. On the left side the pterygoid and palatine regions are nearly perfect and undistorted, save for the interior border of the nares. The nareal opening is long and narrow, the anterior margin a little in advance of the posterior border of the external opening. In front the external border is very close to the dental margin; behind, it is removed a few millimeters. Near the posterior margin of the opening there is a single large tooth, as in *Cacops*, and doubtless there was another on the vomers at the anterior inner border; no other palatine or pterygoid teeth are visible. The infratemporal opening between the pterygoid and jugal margin is shorter and narrower than in *Cacops*, and the lateral process, doubtless corresponding to the transpalatine, is smaller. The basisphenoid process of the pterygoid is stout, transverse, and nearly horizontal. Evidently the structure throughout of the palatal surface was quite alike in the two genera. Parts only of the walls of the rhinencephalic chamber are preserved.

"The maxillary teeth, which extend backward to opposite the beginning of the infratemporal opening, are all very small and are much more numerous than in *Cacops;* I count about forty-five in each maxilla. Those preserved entire are scarcely more than 2 mm. in length.

"The mandibles, which, with the exception of the extreme anterior end, are preserved complete, are, like those of *Cacops*, slender bones, deepest immediately in front of the cotylus, with a relatively high coronoid process, which fitted into the infratemporal fossa. I count about thirty-five teeth in each dentary, as preserved. The external surface, at least posteriorly, is closely impressed with circular or oval pits, like those of the cranial table."

The carapace of the *Dissorophidæ* differs materially from that of the *Aspidosauridæ*. This point was not appreciated by Williston, who placed the genus *Aspidosaurus*, with query, in *Dissorophidæ*, and also suggested that the genus *Alegeinosaurus* was probably synonymous with *Aspidosaurus*. In the *Dissorophidæ* the dermal plates overlie the expanded neural spines, but are not united with them. In the *Aspidosauridæ* the armor is composed of the expanded neural spines alone. A cross-section of the dermal armor in the New York specimen shows that from the center of the expanded neural spine a strong process runs forward and lies in a groove on the upper surface of the next preceding vertebra. Figure 45 illustrates the characters of the genus as shown in the type specimens of *Dissorophus* and *Otocœlus*. The following discussion of the carapace and axial skeleton is taken from Williston (73):

"*Carapace:* The carapace, as preserved, is of essentially the same character as that of *Cacops*, but of a far greater development. In the series, as adjusted, there are indications of twelve or thirteen vertebræ participating in the shield and others possibly are lost. The whole number may have been the same as in *Cacops aspidephorus*, that is, fifteen, but I suspect there were more. The first dermal shield, covering three or four vertebræ, appears not to have been intimately associated with the spines of the vertebræ. It is very large, not much broader than long, and heavy. Its front border is very obtusely angular in the middle, with the borders receding and rounded. The lateral borders are subparallel and gently convex in outline. The posterior border has a gentle emargination in the middle with the lateral sides slightly convex behind. The planes of the sides have an angle of nearly forty-five degrees with each other and are broadly rounded in their union.

The dorsal surface is rather deeply pitted, the depressions rounded or oval with reticulating ridges between them. The under surface is smooth, and appears not to have been underlaid with lateral expansions of the spines. Back of this shield, on the under side, there are nine spine dilatations, the first six or seven complete in the specimen. They are thin, flat plates, apparently co-ossified with the rather slender spines above, directed nearly transversely, with a less angle of declivity than has the nuchal or scapular shield. The outer extremities are narrowed or obtusely pointed, their upper surface beveled both in front and behind for the dorsal shields. Their surface is smooth throughout.

"The dorsal shields are rather stout, elongate bones, rounded on their outer extremities, pitted on their dorsal surface like the nuchal shield, form-

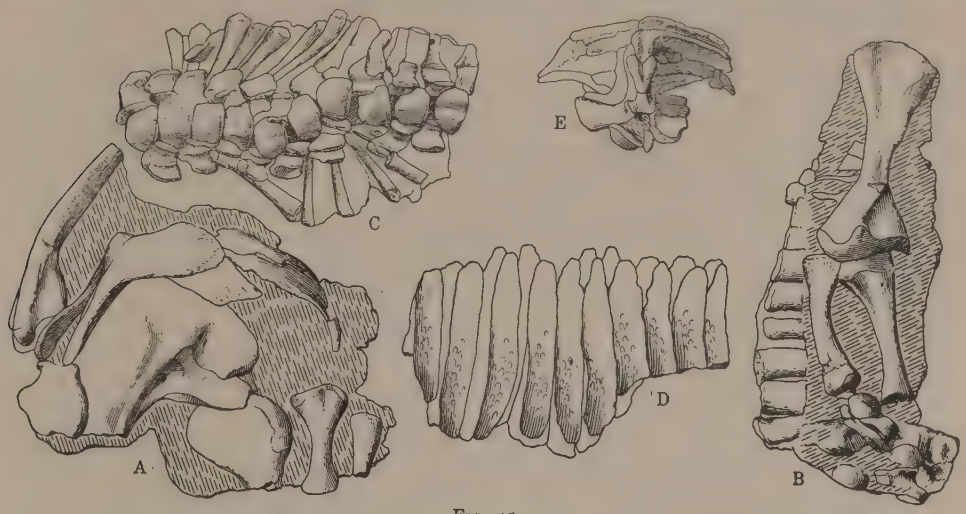

FIG. 45.

A. *Dissorophus* (*Otocœlus testudineus*). No. 4343 Am. Mus. × ½. Lower view of thoracic region, showing interclavicle, clavicles, cleithra, and scapula.
B. Same; lower surface of a fragment, showing the femur, tibia, and fibula.
C. *Dissorophus multicinctus*. No. 4593 Am. Mus. × ½. Lower view of a portion of vertebral column.
D. Same; upper view of a portion of vertebral column, showing dermal plates overlying and alternating with the expanded neural spines.
E. Same; anterior view of same fragment shown in C and D, showing the relation of dermal plates to neural spines.

ing a rather uniform arc of a circle, with less steepness on the sides than that of the nuchal shield. These shields, thick in their middle line, thinned along their anterior and posterior margins, leave a space of from two to four millimeters between their adjacent borders, in which the smooth surface of the spinal expansions is visible.

"*Vertebræ:* Not many of the vertebræ are preserved, and such as are, are not in the best condition. They do not seem to differ from the vertebræ of *Cacops* in any essential respect. The vertebra connected with the first dorsal spinous expansion has the proximal end of the ribs attached. It is broad and flat, articulating with the transverse process and hypocentrum like the early ribs of *Cacops*. The ribs evidently had no uncinate projections like those of *Aspidosaurus* or *Euchirosaurus*. The under surface of the more posterior expansions is shown characteristically in Broili's figure (*Paleontographica*, LI, plate V, 5*b*).

"*Scapula:* The scapula of *Dissorophus* differs markedly from that of *Cacops* in its greater robustness and in its more upright position. The posterior border is thickened and has a more pronounced convexity near its middle. The preglenoid facet is very prominent as a sharp ridge, immediately below which is the opening of the infraglenoid or supracoracoid canal and, close by, back of the lower part of the same facet, is the opening of the glenoid canal. The ridge continuous with the preglenoid facet is less prominent than in *Cacops;* the post-glenoid part, or metacoracoid, is more extensive, the concavity between it and the hind border of the shaft is deeper. On the inner side the deep fossa into which opens the supraglenoid and infraglenoid canals is deeper and shorter, and the epicoracoid portion is much broader below and internally to this fossa. The opening for the glenoid canal on the inner side, as in *Cacops* and *Trematops*, is opposite the lower part of the fossa.

"The *cleithrum* or supraclavicle is a much heavier but more slender bone in *Dissorophus* than in *Cacops*. It lies, as in that genus, loosely over the top of the scapula, not suturally united with it, arching roof-like over the top. In front it descends over the rounded superior anterior angle of the scapula, fitting into a depression of that bone. Below, it unites by a long oblique suture with the upper end of the clavicle, extending as a narrow, anteriorly curved process quite to the place where the coracoid turns inward, that is doubtless to the sutural line between scapula and coracoid.

"*Interclavicle:* The interclavicle is a broad, gently concave, and thin bone, resembling that of *Cacops*, but larger and broader. It has a rounded, thin border anteriorly, and similarly rounded, thin lateral margins. Posteriorly the bone is broken away, but the thickened median part indicates a posterior median extension, probably as in *Cacops*.

"*Clavicles:* The clavicles are large, broad, smooth bones, meeting each other in the middle line, and covering, for the most part, the interclavicle. They are convex below, with their greatest expansion some distance away from the middle. In the position in which the girdle now is, evidently the normal one, the cleithral ends are directed vertically upward, nearly parallel to each other, with an interval of a little more than two and a half inches between their upper extremities, which are suturally and closely united to the lower ends of the cleithra or supraclavicles. The upper extremity is much stouter and broader than is the case with *Cacops*.

"Upon the whole, the pectoral girdle, both primary and secondary, is remarkable for its stoutness and firm articulations.

"*Humerus:* Of the two humeri, the left is preserved completely save the capitellar angle, while the right has the lower end perfect with the upper extremity wanting. In the figures the capitellar portion has been reversed from the right side. In general shape and structure the bone resembles that of *Cacops* closely, so closely that there may be difficulty in distinguishing them in ill-preserved specimens. The humerus of *Dissorophus* is distinctly stouter, with the ends a little more expanded and the lateral curvatures a little deeper; the entepicondylar expansion is stouter.

"*Femur:* The right femur is preserved in pretty good condition, save the external condyle and a part of the lower portion of the crest. Its resemblance to the femur of *Cacops* is close, but, like the humerus, differs in its greater stoutness. The adductor crest is heavier, and not as deep; the shaft is distinctly stouter. The articular surface for the tibia is rather better

defined than in any of the specimens of *Cacops* examined. The surface is flattened or with a gentle anteroposterior convexity with sharp rims. It is broadest on the inner side, narrower in the middle, and again somewhat expanded from before back on the outer side. The surface looks backward at an angle of about forty-five degrees from the longitudinal plane of the bone, with a slight obliquity inward.

"A large part of the left innominate bone is preserved, enough to demonstrate its close resemblance to the corresponding element of *Cacops*. Nor do the proximal ends of the tibia and ulna differ materially; like all the other parts, they are stouter."

Genus CACOPS Williston. (Plates 17–24.)

Cacops aspidephorus Williston.

Characteristic specimen: A nearly complete skeleton, No. 647 University of Chicago.

The morphological description of this genus and species is taken from Williston's very full account (72).

"*Skull:* Two skulls, nearly complete, and portions of two others have so far been recovered from the matrix. Of these the one in the mounted skeleton was quite complete, but suffered slightly at the front extremity in its collection. The best specimen, however, the one from which the following description has been drawn, was a skull quite complete, attached to another skeleton, from which the posterior end of the mandibles only was lost in collecting. This skull is slightly smaller than the mounted one and had suffered very little distortion. It has been freed from every particle of matrix, even that of the brain and nasal cavities. Unfortunately, in none of the specimens has it been possible to determine the sutures, in part because of the complete ossification of the bones; in part, perhaps, because the removal of the thin investing matrix has obliterated whatever indications of them might have been present. The dermal surface is everywhere rugose, with small, irregular pits and ridges.

"The skull is broad and depressed, broadest opposite the posterior part of the orbits, with a gentle, perhaps somewhat irregular, convexity on the sides. The epiotics project backward strongly, leaving a deep concavity in the middle behind. The nares are large, oval in outline, directed upward, forward, and outward, broadly separated in the middle, and approaching closely the margin of the maxillæ. The orbits are large, subcircular in outline, the opening looking obliquely upward. Near the middle of their front margin the border is angularly thickened, descending in a steep declivity outwardly. In the middle posteriorly, also, there is a similar but more angular thickening, which extends back as a ridge to form the lateral margin of the cranial table, overhanging the otic cavity posteriorly. Almost continuous with the upper orbital margin, there is another elevated ridge running backward and outward to join the lateral border over the middle of the otic cavity. Between these two ridges there is a triangular space of considerable size, more or less depressed in its middle. The least distance between the orbits, near their middle, is but little or no more than one-half the lateral diameter of the orbit. The large parietal opening is located about one-third of the distance between the hind borders of the orbits and the occipital margin in the middle. Just in front of the concave hind border of the table the margin is elevated into a prominent rugose crest or ridge,

highest in the middle, possibly for the attachment of nuchal muscles. The cranial table in front of this transverse rugosity and between the slightly elevated lateral margins is flat or gently concave.

"On the sides posteriorly there is a large cavity, with an angulated slit-like opening at its bottom, forming a false temporal fenestra, which doubtless is merely a greatly enlarged and closed otic notch.* It is bounded above by the heavy overhanging lateral border of the cranial table. The epiotic angles, produced into long horns, instead of ending freely, as in other Stegocephala, turn directly downward to fuse with the quadrate below, inclosing what would otherwise be a simple notch into a large fossa and opening. Its whole exterior and outer surface is roughened like other parts of the skull. The cavity thus inclosed extends angularly at its upper anterior angle to within about 20 millimeters of the middle of the hind border of the orbit and is smooth throughout. At its bottom there is a thin, flat, angular plate, attached to the lower anterior inner side of each epiotic horn, projecting upward and forward to an acute angle, leaving a narrow, slitlike perforation above connected with another in front, reaching the lower part of the cavity, angularly dilated at the upper anterior part. Close to the anterior border of this plate, and near its upper angle, is the projecting end of the stapes, as shown in plate 17, fig. 3.† The upper margin of the perforation in front is formed by a narrow descending plate from the rugose upper border of the cavity. The front wall of the cavity slopes backward from the upper angle to a little above the quadrate articular surface; its smooth wall looks obliquely upward, backward, and outward. It seems probable that this cavity, as thus bounded, was closed by a tympanic membrane, against which the continuation of the stapes abutted.

"The precise limits of the epiotic process are not certain, but a distinct line is evident on one side, indicating sutural attachment with the quadrate along the posterior side of the platelike expansion and to within a short distance of the articular projection. This, I am aware, is an unusual position for the quadrate, with the earslit or opening above and in front of it, but there can be no other interpretation of the structure. The quadrate is well ossified below, fused with the extremity of the pterygoid on the inner side and with the quadratojugal in front below.

"The occipital surface of the skull has, in the middle, a smooth, steep declivity, with the small foramen magnum at the bottom, not more than 5 millimeters in diameter. The high rugosity of the posterior border of the cranial table overhangs slightly this declivity, forming a fossa into which doubtless were inserted the strong neck muscles. Just outside of each condyle there are the usual two cranial foramina at the base of the paroccipital processes, which extend outward, joining the epiotic on the under side and turning downward to terminate at or near the upper posterior corner of the quadrate. Between this paroccipital process and the roof, at each side, there is a moderately large post-temporal vacuity leading into a deep cavity just inside the 'tympanic' rim of the ear cavity and below the roof of the skull.

"The structure of the under side of the skull, while not departing far from the usual stegocephalan type, is somewhat remarkable. The palatal

* A closed otic notch is not unknown among Stegocephala. See Woodward, Proceedings of the Zoological Society, 1904, p. 170, plate XI, *Capitosaurus stantonensis* Woodward.

† The plate references given in this description are for this paper, not the original.

cavity as a whole had a high arched roof, with a slender, almost vestigial, parasphenoid dividing the large pterygoidal vacuities so characteristic of the amphibia. The internal nares are larger than the external ones, situated either close to the teeth, with their front margin almost below the hind margin of the external nares. On the inner side of each there is a stout, conical, recurved tooth, about 10 or 12 millimeters in length, and another like it is situated near the posterior margin of the orifice, not far from the maxillary teeth. These are the only teeth located on the palatal surface. The palatines or conjoined palatines and pterygoids on each side posteriorly and internally to the nares slope strongly upward. In the middle in front the vomer or anterior end of the parasphenoid is about 15 millimeters in width where it joins the palatine shelf, narrowing to about 4 where it joins the rhinencephalic chamber. Posteriorly the arrangement of the basicranial bones is very similar to that of *Trematops* or *Eryops*. The ossified basisphenoid sends downward and outward a stout basipterygoid process to join the pterygoids on each side, the juncture indicated by a thickening as in *Trematops*. Outwardly the pterygoids form a vertical plate, probably with the conjoined epipterygoids, reaching to the cranial wall, save for a small vacuity near the roof, leading into the deep temporal cavity under the roof, into which the post-temporal vacuity also opens, a cavity open below back of the pterygoids between the basicranial bones and the posterior wings of the pterygoids. In the middle the parasphenoid continues forward from the basisphenoid as a slender rodlike bone nearly to the flat anterior end. For a short distance it forms a high bridge, above which in front is the inferior opening of the parietal foramen. For the larger part of its distance, however, it is closely united as a thick ridge to the lower side of the elongated rhinencephalic chamber. Between this chamber and the closed brain-chamber behind there is a large orifice on each side for the escape of the optic nerves. This elongated arched chamber has its anterior borders also free and curved a little back of the anterior margin of the orbits. In front of this the roof of the skull has been somewhat pressed down upon the palatal bones, but there was evidently in life a high cavity for the nasal region, in which are various indeterminate bone remains, doubtless the ethmoidal and turbinate. A little in front of the basisphenoid the pterygoids give off a rounded or subangular process, much as in the allied forms, narrowing the opening of the infratemporal fossa, which is broad and deep behind, where its thin upper posterior roof forms the anterior inferior wall of the otic cavity.

"The basisphenoid is concave in the middle; on either side it has a flattened basisphenoid process, as in *Trematops*, directed downward and backward, underarching a rather deep fossa. Opposite these on either side is the root or base of the pointed, stylelike stapes, which is directed outward and backward to terminate, as already described, at the upper angle of the quadrate, in the auditory vacuities. Whether or not it has a foramen at its base I can not say. Above and in front of this, turned upward to reach nearly to the inner surface of the superior tympanic ridge, is the prootic bone.

"A comparison of the structure of the basicranial region with that of *Trematops* shows great similarity, quite confirming my suggestion that the pseudotemporal vacuity is in reality merely the closed otic notch for the opening of the external ear. The opening in *Trematops*, however, is far smaller than in *Cacops*, and extends somewhat further forward toward the

orbit. The small size of the parasphenoid in the present genus also explains its apparently entire absence in *Trematops*, though it is not improbable that the rhinencephalic canal in *Trematops*, were it preserved complete in the type specimen, would show the remains of the parasphenoid coalesced with it as in *Cacops*.

"The maxillary teeth in *Cacops* are all small and of nearly uniform size, in an uniform closed series. I count about 20, but it is possible there may have been a few more.

"The mandible is remarkable for its slenderness. Posteriorly it has a broad expansion, but the ramus from the middle of the orbits forward is slender. A deep fossa is present in front of the condyle, and the median symphysis in front is a little expanded. It has apparently the same number of teeth as in the maxillæ, and all, like them, are of uniform size.

"*Vertebræ:* The vertebral column of the mounted skeleton was apparently quite complete as it lay in the matrix in association with skull and limbs. In the removal of the thin incrusting matrix, however, a few of the pleurocentra of the anterior vertebræ and some of the small elements of the tail were lost, notwithstanding the most scrupulous care. Of these, only the possible pleurocentra of the atlas and the dorsal elements of the first 5 or 6 caudal vertebræ have any morphological significance; future preparations of other skeletons yet contained in the matrix will doubtless complete even these small details. The column as found was continuous from the skull to the tip of the tail, without break, save that the last few caudal vertebræ were slightly angulated from the rest of the series. The presacral vertebræ had a gentle, sinuous curve, with the convexity to the right as far back as the end of the dermal carapace, to the left from thence to the sacrum. There is also a slight vertical sinuosity in the same regions, convex above anteriorly, below posteriorly. These curvatures seemed so normal that no attempt has been made to reduce them in the mounted skeleton, and I have figured the column as it lay. A slight pressure to the left has crowded the ribs upward on that side and downward on the opposite side, but to a very slight extent only. The perfect union of the different elements, at least as far as the beginning of the chevron caudal vertebræ, removes all possible doubt as to their number and relations—21 presacral, 2 sacral, 6 pygals, and 15 or 16 chevron caudals. The spines, save those of the first 2 vertebræ, are of nearly uniform length throughout the carapacial series, 15 in number, a trifle longer perhaps in the anterior and middle region, and a little more slender in the last 3 or 4. Those of the free presacral vertebræ are progressively shorter and less stout. Throughout the series covered by the carapace they are slightly thickened at the upper end, with the anterior and posterior margins thinned, and with a lateral ribbed thickening on each side near the middle, as though for the support of the terminal expansion. Covering the top of each spine there is a rooflike expansion, wider in the middle and narrowed at each lateral end. Their sides slope downward at an angle of about 45 degrees to the full width of the superincumbent dermal scutes. The anterior margin of these plates is uniformly beveled for articulation with the posterior margin of the superincumbent intercalated dermal scute. The posterior beveling is much broader in the middle. Presumably these expansions are outgrowths from the top of the spine, cartilaginous in origin, but of this I do not feel entirely assured, since in every case where I have removed them I have found what appears to be a sutural

surface, and the top of the spines is rounded on the margin, with an extrant angle between it and the plate. The surface of these expansions is smooth, both above and below. The narrowed outer extremities are either rounded or with a slight emargination. The first of these expansions, that of the second vertebra, is small, subtriangular in shape, with rounded corners, and appears not to have been covered by a dermal scute. The second expansion is larger, becoming broader behind, and is covered, on its posterior part only, by the first dermal scute. The posterior end of the carapacial series tapers more gradually than does the anterior to a narrower extremity, and like that has, apparently, no dermal plate over the last of the series, the penultimate spinal expansion supporting the posterior margin of the last dermal shield. Throughout this series the thinned expansions of the spines above, anteriorly and posteriorly, touch each other in the present curved condition of the column. In the most anterior part of the column, however, the hypocentra are slightly separated, with one longer interval, producing a slight convexity of the series below. It thus seems certain that the position in which the column was found, and which has been retained in the mounted specimen, was a normal one for the living animal; that is, with a gentle convexity anteroposteriorly of the carapace, and a slight concavity below. Nor would it have been possible for the living animal to have fully straightened out the column without actually dislocating the zygapophysial articulations. A slight lateral bending was possible in life, as shown by the position in which the bones were found; but even this could not have been extensive in the front part, since the free dermal plates which glided smoothly over the fixed spinous expansions would have met each other at their lateral extremities, if the curvature was at all decided. Back of the carapace, however, a greater flexibility was possible, since the zygapophyses here are somewhat larger, and the free spines were separated above by a greater interval.

"*Carapace:* The dermal plates are of nearly uniform length, increasing slightly in expanse to the middle of the series—that is, at the summit of the dorsal convexity. Each fits accurately and closely over the contiguous borders of the adjacent spine roofs, separated from each other by a space of 1 or 2 millimeters. It is evident, from the structure of the spine expansions with the greater beveling in the middle behind, that the chief motion was at the anterior part of each dermal plate. The upper surface of these plates is slightly irregular, with shallow depressions or pits, the margins in front and behind parallel, with a slight obliquity backward; their outer angles are slightly rounded, and their outer, thin borders are nearly straight, or with a slight emargination. Each of these dermal plates is composed of two elements, a median longitudinal suture being evident in many of the shields. In the middle of each above there is a shallow groove bordered on each side by a slight elevation.

"In the structure of the dorsal shield or carapace the genus is identical with *Dissorophus*, save that the carapace of the latter genus is very much more extensive, covering practically the whole of the dorsal side of the animal and probably extending further back. Furthermore, in *Dissorophus* the anterior shield is very large, covering several vertebræ, very much like the anterior shield in certain armadillos.

"*Hypocentra:* The hypocentra, like the arches, are of nearly equal size and extent throughout, rather strongly and smoothly convex from side to

side, gently concave anteroposteriorly. The second to the eighth back of the atlas have, on each side, near the upper angle posteriorly, a facet or protuberance for the capitular articulation of the rib. The first hypocentrum back of the atlas is smaller than the succeeding ones; it is shorter and has more acute lateral margins, and is, apparently, without facets for the capitular articulations. The second hypocentrum is also somewhat smaller than the succeeding ones, but is provided with a parapophysial protuberance on each side.

"*Pleurocentra:* Of the first four vertebræ back of the atlas the pleurocentra were not recovered; they doubtless had dropped out of their places and were not recognized in the matrix, since a slight depression of this part of the column had loosened all the elements somewhat. However, in the connected series places for them are shown with articulations indicating but little variation in size from that of the following ones. In size the pleurocentra of the remaining vertebræ are nearly uniform, perhaps slightly longer anteriorly than posteriorly. Each articulates broadly with the posterior side of the pedicle of the neurocentrum, and less extensively with the anterior side of the following neurocentrum, as shown in plate 18, and by the narrowed lower extremity with the posterior superior margin of the hypocentrum, fitting into the angular space between the adjacent neurocentra. The large flat sutural surface for union with the preceding neurocentrum indicates a close, firm union, while that with the succeeding neurocentrum and hypocentrum is more rounded. The pleurocentrum of the first presacral vertebra is narrower than the preceding one. The pleurocentra of the two sides of each vertebra are closely approximated in the middle above a small concavity on the upper side of the hypocentrum, leaving in the articulated parts a persistent notochordal canal.

"The zygapophyses are stouter in the free or lumbar portion of the column than in that part covered by the carapace, as would be expected, since the comparative rigidity of this part prevents extensive motion of the individual vertebræ upon each other. Their articular surfaces look uniformly upward and inward, and downward and outward, at an angle of something less than 45 degrees.

"The diapophyses arising from the neurocentra increase rapidly in vertical extent of their rib attachment as far as the eighth, the border continuous with the parapophysial projection on the hypocentra. The ninth suddenly decreases in width, with a wide interval between its lower end and the hypocentrum, which has no parapophysial facet. From the ninth the transverse processes are narrower, with the extremity for rib articulation of but moderate extent. Throughout the series the processes are directed almost transversely outward, with the upper nearly horizontal margin a little thickened and rounded; the upper margin arises a little below the zygapophyses anteriorly, a little lower down posteriorly. The rib margin is straight or gently sinuous from above downward, thinned below and slightly emarginated, ending, as has been described in the first eight, in apposition with the parapophysial facet on the hypocentra. The lower end of the rib margin is considerably in advance of the upper. Beginning with the ninth, where the ribs become single-headed, the transverse processes are of nearly uniform width, the articular surface for the rib placed obliquely to the vertical line. Beginning with the seventeenth vertebra, the first behind the carapace, the diapophyses shorten rapidly, becoming almost

sessile in the last two, in which the rudimentary ribs seem to be anchylosed to their extremities.

"*Atlas:* The atlas was preserved in this specimen in place. It is somewhat eroded and does not seem to differ from a better preserved specimen belonging to the closely related genus *Dissorophus*, which I have figured in plate 23, fig. 11. This vertebra seems to be a single element, though doubtless it is composed of coalesced hypocentrum and neurocentra; but I can distinguish no sutural lines. The anterior surface shows two facets for articulation with the occipital condyles. On the posterior side the body has a deep concavity, pierced above its middle by a small notochordal foramen. The neuropophyses are simple processes, of nearly uniform width, and flattened; they lie closely in apposition with the sides of the spine of the second vertebra. The same condition is found in *Eryops* and *Trematops*, and is doubtless the usual structure of the atlas in the rhachitomous amphibians. Back of the neurocentra I find no articular surface for the attachment of the pleurocentra, though the anterior border of the next vertebra seems to indicate the presence of small pleurocentra.

"*Sacrum:* In *Cacops* we have two well-developed pairs of sacral ribs broadly attached to the ilia. Of these, the first pair is a little larger and stouter than the second, though differing otherwise but slightly. The stout vertebral ends have two articulations, with a small non-articular surface between them, the upper and larger one attached firmly to the neurocentrum, the lower to the upper border of the hypocentrum, which again presents a parapophysial protuberance for its union. The somewhat crushed condition of the arches of the sacral vertebræ, as they were found lying in the pelvis, prevents the determination with certainty of the relations of the neurocentra to the hypocentra, but I suspect that they articulate on the sides with the ribs only and not with the hypocentrum. Beyond the articular head the stout shaft of the ribs is constricted for a short distance into an oval form, and then suddenly expands into the large flat or outwardly concave portion for union with the ilium. This thinned expansion of the first rib has an emargination on the upper posterior border, in which fits loosely the lower anterior border of the second rib, the two forming an elongated, nearly plane surface, which extends the whole length of the lower part of the ilium in its greatest width nearly opposite the upper part of the acetabulum. The first sacral hypocentrum is rather larger than the preceding one, with a parapophysial facet at each side for the rib. The second hypocentrum, of nearly equal size, has also a like facet for the rib on each side. The neurocentra of these two vertebræ are in part missing, apparently due to some accident before fossilization.

"*Tail:* The tail was preserved complete, but the flattened end was slightly dislocated, doubtless due to its thin, compressed form. The small bones of the neural side of the first six, or pygal, vertebræ were so small and so confused in the matrix that not much could be made of them. The six pygal hypocentra were found attached in a continuous series. There is a slight, very slight, possibility that an additional one may have been lost in the matrix at the place where the dislocation occurred, but I think not. The tail could not have been more than a fourth of an inch longer or shorter than is shown in the restoration. The first six, or pygal, hypocentra decrease rapidly in length. With the fifth is a short, rudimentary rib, a mere pointed tubercle, and several similar ribs were found loose in the matrix.

"Beginning with the seventh, or possibly the eighth, caudal there is a continuous series of fourteen or fifteen with chevrons, some of them, as shown in the drawings, with the neural arches attached. It required a critical examination with a lens to distinguish the very small pleurocentra of the posterior ones; that I did distinguish them I am quite certain. The hypocentra are angular; the lower posterior part extended into stout chevrons, which were perforated near their base for the hæmal canal. The distal part of the tail was thin and high, possibly used as a rudder-like organ in life.

"*Ribs:* Many of the ribs have been removed from their encrusting matrix with but little or no injury; some of the posterior ones, because of their extreme delicacy, could not be worked out completely. The first eight pairs have broadly expanded proximal extremities, with a distinct separation, save of the first pair, of the rounded and thickened capitulum from the more elongated and thinner tubercle. The upper border is nearly straight or gently convex on the proximal portion, convex beyond; for the three distal fourths or more the shaft is slender, gently flattened, oval in cross-section, and is curved downward. Beginning with the ninth rib, the proximal expansion is much less, and there is no distinction into capitular and tubercular articulations; the shaft is more slender. The ribs increase gradually in length to the ninth and probably to the tenth. Beyond this they decrease more rapidly in length. In the last two pairs, at least, they are reduced to tuberculiform rudiments, ending pointedly, and are apparently coossified with the diapophysis.

"From the tenth to the eighteenth only the proximal parts were worked out—that is, their precise lengths could not be determined.

"*Scapula coracoid:* The scapula coracoid (plates 19–20) is a relatively large bone, with no indications of sutural division into its supposed component parts. The blade is moderately expanded above, gently concave on its outer, convex on its inner, surface. Its upper border is a little convex longitudinally, its edges sharply truncate for cartilage. The posterior border is thickened to the beginning of the glenoid concavity; the corresponding anterior border is thinned.

"The posterior border divides to include the supraglenoid fossa, perforated at its bottom by the supraglenoid foramen. The outer border continues downward, and by a gentle curve backward to terminate in the oval preglenoid facet, which looks downward, backward, and outward. The inner margin, the thicker, extends downward, inward, and backward, with an anterior curvature. In one specimen the end is angularly truncate, in all probability for a small metacoracoid that was not ossified. In the others it continues in a thin border back of the margin of the posterior glenoid facet. This latter facet is near the lower part of the bone, an elongate concave surface, with sharp margins posteriorly, and is opposed to the anterior facet already described. Between these two facets and a little above them the glenoid foramen pierces the bone obliquely backward to open on the inner surface a little back of the border of the subscapular fossa, in which the supracoracoid and the supraglenoid foramina both open. The lower anterior part of the bone is thickened, with truncate edges, and is convex in outline. The upper end of the cartilaginous border continues backward as an angular thickening, nearly on a level with the upper border of the preglenoid facet. The thickening extends as a ridge a short distance backward. In much probability this ridge limits the upper border of the epi-

coracoid, since, in the immature specimen already spoken of, a sutural line seems to run directly backward below the upper edge of the preglenoid facet, quite as in *Varanosaurus*. The lower edge of the preglenoid facet continues as a rounded border downward and forward part way to the lower margin of the bone. In the cavity thus formed at the lower end of the facet is the opening of the supracoracoid foramen. On the inner surface of the bone, near the middle, extending downward subparallel with the anterior border of the bone, is the anterior border of the subscapular fossa. In its middle part the free border overhangs a deep fossa looking backward, at the upper end of which opens the supraglenoid foramen; at the lower end is the opening of the supracoracoid foramen. Back of this margin the bone is convex, and is pierced by the inner opening of the glenoid foramen.

"*Cleithrum:* The cleithrum, found in position on either side, is remarkable for its large size. Its lower part is a long rod closely attached to the anterior margin of the scapula as far as the angular thickening I have described; it is overlapped through nearly its whole extent by the upper part of the clavicle. The upper part of the cleithrum is broadly dilated and thin, covering the upper border of the scapula to its hind angle and arched inward. Its borders are very thin, convex above, concave below; the posterior thin margin is nearly straight. The bone above forms a sort of roof convex outwardly, concave inwardly.

"*Clavicles:* The clavicles are small, somewhat spoonshaped, with curved handle. The upper, slender part is closely applied to the outer, anterior side of the lower, rodlike part of the cleithrum, reaching nearly to the dilated portion. The lower end, curved inward and a little backward, is dilated with thin margins, concave on the inner side where it articulates with the interclavicle, convex on the exterior or lower surface. It underlaps the interclavicle and partly covers the lower anterior border of the epicoracoid.

"*Interclavicle:* The interclavicle is a small, thin bone, dilated and thinned in front, where it overlies the ends of the clavicles, which touch in the middle. The posterior extension or 'stem' is short, not as long as the expanded part.

"*Humerus:* The humerus is of the usual temnospondyle form, differing from that of *Eryops* and *Trematops*, especially in the absence of the entepicondylar process, so conspicuous in the former and in *Euchirosaurus*. It is broadly expanded at either extremity in planes nearly at right angles with each other, and has a rather slender shaft in the middle. The lateral or radial process is very stout; the medial or ulnar process is indicated by a slight ridge or elevation just below and in front of the inner extremity of the proximal articular surface. The digital fossa on the inner side is rather shallow and broad. The short shaft is subcylindrical in cross-section, with a sharp ridge running from the outer side of the lateral process to terminate in the supinator ridge. The capitular surface for the radius is subhemispherical in shape, looking mainly forward. The trochlear surface for the ulna is small. The inner, condylar border is moderately dilated and relatively thin; the ectepicondylar or supinator border thick. There is no indication whatever of the ectepicondylar process below the lateral process on the outer side.

"*Radius* (plate 23): The radius has a very slender shaft in the middle, and is broadly and thickly expanded at either end. The posterior border is nearly straight, the anterior deeply concave, the two lateral borders nearly symmetrically and deeply concave in outline, the extremities of nearly

equal width and nearly transversely truncate. The proximal end has a groove on the posterior side thinning the inner articular surface.

"*Ulna* (plate 23): The ulna is a remarkably slender bone in comparison with the radius—slender in comparison with the bone in other genera of Permian air-breathers. It has a slender and curved shaft on the distal three-fifths, the distal extremity only a little widened, with its greater diameter at right angles to the greater diameter of the proximal end. The olecranon is very slightly produced, and the articular surface for the humerus is oblique to both axes of the bones; the inner side of the proximal end is flattened.

"Two bones of the proximal row of carpals with several phalanges were found close to the bones of the left forearm. They are relatively small. Their characters may be seen in the figures (plate 21, fig. 3).

"*Pelvis:* The pelvis (plate 22, fig. 1) is very strong and stout, the two halves meeting in a very firm symphysis, which forms an obtuse ventral ridge most protuberant in the middle below the acetabulum. The pelvic cavity is deep and spoutlike, nearly semicircular in transverse outline, with the lateral margins anteriorly and posteriorly slightly flaring. The anterior border is emarginate in the middle, the sides convex in outline, with a notch. The posterior margin is slightly narrower than the anterior, and has a deeper emargination in the middle line, the sides somewhat thinner, with convex borders to the outer, somewhat angular margin. The posterior margin of each innominate is concave from the upper angle of the ilium, with a pronounced angular projection in the middle of the concavity at the junction of the ilium and ischium; this border is rather thin throughout. The front border is likewise concave throughout from the upper angle of the ilium, with a slight convexity below the middle at the place of junction between the ilium and pubis. This border is much thicker than the posterior, and flares outwardly below. The acetabulum is deep and large, with its greatest concavity below its middle. It has a distinct and rather protuberant rim, save at the upper posterior part. Its upper border on the ilium is marked by a small but distinct process overhanging the concavity. The lower margin on the ischium is very prominent, forming an angular projection to the full width of the bone, while the stout expansion of the pubis in front limits the deepest concavity of the acetabulum. The shape of the acetabulum would indicate that the chief pressure of the femur was directed nearly horizontally and a little backward. The lower rim is nearly horizontal, deeply concave anteroposteriorly, overhanging the almost horizontal outer surface below. The pubes flare outward on each side in front from a subangular line, running downward and inward through the inner orifice of the obturator foramen to either side of the median emargination of the front border. The triangular surface either side thus limited looks at an angle of about 45 degrees upward from the horizontal position of the pelvis and slightly inward, and is gently convex from side to side. The under surface on the sides of the conjoined pelvis is nearly horizontal laterally, descending in the middle into a broad obtuse ridge, broadest and deepest a little in front of the middle. In front the downward curvature of the pubes leaves a concavity, at the bottom of which is the external opening of the obturator foramen, very near the middle of the pubis anteroposteriorly, and opposite the greatest protuberance of the pubic margin, not far from the border of the acetabulum. The front border of the pubes is roughened

for cartilage. The sutures separating the elements are very clearly shown in the present specimen. Those between the ilium and ischium and pubes begin on the margins near the middle of the convexities described and run downward to meet a little below the middle of the acetabulum, that for the ischium being a little longer than the one for the pubis. The puboischiadic suture runs directly inward through the deepest part of the lower margin of the acetabular rim, the length of the ischia below being about a fifth greater than that of the pubes. The depth of the lower pelvic border is due solely to the breadth of the symphysis, the upper surface of the pelvis in the middle showing no corresponding concavity.

"*Femur* (plate 22): The femur is remarkable among temnospondyles for its slenderness and the great development of the adductor crest. The proximal articular surface has its transverse diameter but little greater than the anteroposterior one, narrower on the outer side, more convex on the inner, where the articular surface extends more on the ventral side. The digital fossa is small and shallow. The adductor crest arises near the upper part of the bone, is directed outward for a short distance, and then is nearly straight to its distal end near the lower fifth of the bone, and near the middle of the popliteal surface. The shaft of the bone for about the middle two-fifths is very slender, almost cylindrical, save for the crest behind, and is straight. The distal expansion of the bone begins a little above the lower fifth and is a little greater than the proximal one. The lateral linear concavities of the bone on the two sides are nearly symmetrical. The distal articular surface of the bone has sharp borders, indicating a considerable amount of cartilage. The end is much broader transversely than from before backward. The transverse tibial surface looks downward and a little backward and inward. The fibular surface is a little longer from side to side and looks markedly outward, backward, and downward. Its width in the inner side is more than one-half of the whole width of the extremity, with narrow extensions both in front and behind. The fibular condylar projection is much thinner and less extensive than the tibial. The extensor groove in front of the distal end is broad and moderately deep, limited on the outer side by a high and rather sharp ridge. On the back side a less prominent, more obtuse ridge opposite the dorsal ridge, and connected with the distal end of the adductor crest, separates a shallow concavity on the inner side from a narrower and deeper one on the outer side.

"*Tibia* (plate 23): The tibia is more than three-fourths the length of the femur. Its upper extremity, as usual, is broadly expanded and massive, the lower less expanded and more cylindrical. The upper surface for articulation in the normal position of the bone is broad from side to side and about two-thirds as wide from before back, thicker on the outer than on the inner side, with an emargination on the outer anterior side, the anterior border internally convex, the posterior border nearly straight. The surface is gently convex from side to side, nearly flat anteroposteriorly, and looks on the whole upward and a little backward. The distal articular surface is suboval, its longer diameter running from behind outwardly and anteriorly, with the internal border convex, the outer posterior border more nearly straight or gently convex. The shaft is slender in its middle, broader in section from before backward, and is flattened on the inner side. The inner border of the bone is deeply concave, the outer almost straight, save at the lower end. The posterior surface of the bone is flattened on the upper

expansion, bounded inwardly by a sharp sinuous crest, which becomes confluent with the convexity of the distal extremity.

"*Fibula* (plate 23): The fibula is shorter than the tibia, flattened upon its posterior inner surface, and convex from side to side on the opposite. The outer thinner margin is nearly straight to the lower fourth, where it curves inward. The inner border is deeply concave, more so on the lower half. The lower extremity is more expanded than the upper, and is also thicker, strongly convex in front, and somewhat concave on the posterior surface. In the vertical position of the bone the upper articular surface is nearly horizontal, while the lower is directed at an angle of about 20 degrees inwardly.

"Associated with the leg bones were found a number of tarsal and phalangeal bones, figures of which will be found in plate 21, figs. 1 and 2. Their precise position can not be determined, more than that two of the tarsals belong in the proximal row and three of the toe bones are metatarsals."

Family TREMATOPSIDÆ Williston (page 66).

Genus TREMATOPS Williston (page 67).

Trematops milleri Williston (page 67). (Plates 14–16.)

Characteristic specimen: No. 640, University of Chicago.

The morphological description here given is a reprint of Dr. Williston's original article (71).

"*Skull:* The skull of *Trematops* is remarkable, not only among amphibians, but also among Permian vertebrates, for the association of certain peculiar characters, widely distinguishing the genus from any other now known. The chief of these characters are: the possession of a median, unpaired rostral opening leading into a palatine vacuity; greatly enlarged antorbital vacuities; a temporal fenestra; and the apparent absence of the parasphenoid bone of the palate. In the skeletal characters, aside from those of the skull, the genus does not differ much from *Eryops*, so far as known, and doubtless the skeletons of each, when fully known, will show a like agreement throughout.

"In shape the skull is subtriangular, its width posteriorly being but slightly less than the length from premaxillæ to occipital condyles. Its surface is coarsely and rather deeply pitted, but presents no traces of mucous canals that I can distinguish. The face is markedly constricted just in front of the orbits, the facial region showing a slight lateral convexity on the outer sides of the large antorbital vacuities. Back of the orbits the 'table' of the skull is broad and nearly flat, perforated by the rather small parietal foramen near its middle. The orbits are oval, their greater diameter oblique to the longitudinal axis of the skull, their borders thickened in front and behind, but thinner above and below, with the plane of their margin looking obliquely forward, upward, and outward. Immediately back of the orbit at its outer part, the table turns downward, forming the anterior bar of the temporal vacuity. The upper margin of this vacuity is perfectly preserved on the left side, but the fragments forming it were not recovered for the right side of the skull. It is thinned, in outline gently concave and turned outward, and, posteriorly, a little downward, forming the lateral margin of the flat table of the skull. The natural character of the border is beyond dispute, the small pittings of the surface continuing quite to the junction of the upper with the lower surface of the cranial bones. There is no possi-

bility of its union, either by suture or fracture, with the lateral walls of the skull. In front the vacuity continues in a shallow, lateral groove, nearly as far forward as the orbital margin. On the right side, the upper margin of the vacuity, as stated, is not preserved, but the natural, rounded border of the opening is found on the lower and partly on the front side, giving, with the left side, practically the outline of the vacuity throughout, save at the narrowed posterior end. The cavity was oval in shape, about twenty millimeters in length, looking outward, and a little upward and forward.

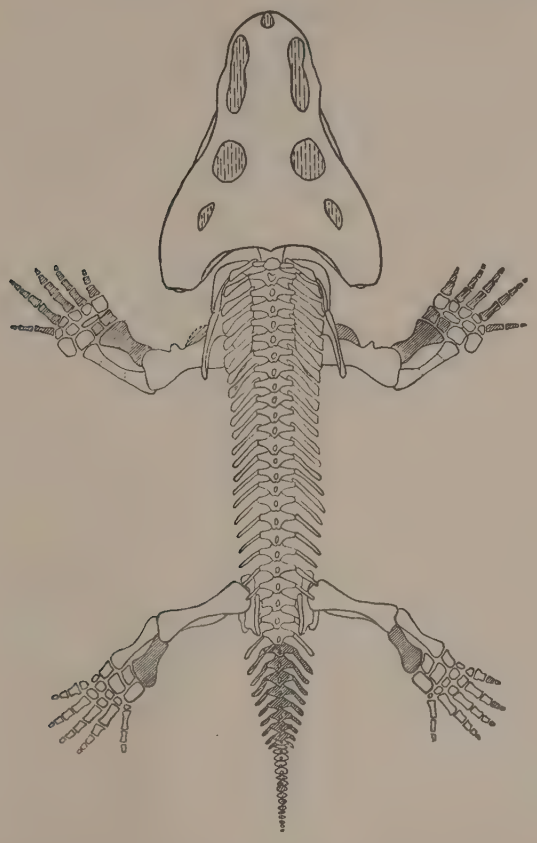

FIG. 46.—*Trematops milleri*. No. 540 Univ. of Chicago × ⅛ circa.
Restoration of skeleton. According to Williston.

There remains the bare possibility that the enlarged vacuity was connected by a slender and sinuous isthmus with the outer posterior margin of the skull, but I do not think so. In position, it is seen that the fenestra is nothing more or less than a greatly elongated and closed epiotic notch, and this interpretation is confirmed by the disposition of the bones on the under, palatal side of the skull. Other genera of stegocephs have the epiotic notch closed posteriorly, but I know of none in which it extends nearly so far forward as it does in this genus. As an epiotic vacuity it conveys the suggestion that the origin of the lateral temporal vacuity in the double-arched or

saurocrotaphic reptiles has arisen, not by a natural trephining of the skull wall, but by the inclusion of an epiotic notch. From the fact that the so-called squamosal bone borders the vacuity above, it would hardly seem to be homologous with the superior temporal fenestra. However, it is by no means sure that the superior bone is the real homologue of the squamosal of the higher animals. I have followed Baur in so considering it, but I by no means believe that its squamosal or supratemporal character has yet been demonstrated.

"The sutures, for the most part, in the skull are indistinguishable or distinguishable with difficulty from the cracks. On the upper surface of the table, however, they are very conspicuous, as shown in the illustrations. The parietals, it is seen, are rather small bones, uniting by a transverse suture with the so-called supraoccipitals behind.* The shape of the postfrontals is clearly shown, but the postorbitals are indeterminable. Nor can I make out the limits of the epiotics and 'squamosals' or 'supratemporals,' though the two bones very clearly form the outer part of the table. The frontal bones terminate a little in front of the orbits by a nearly transverse suture, and, of course, the nasal bones form that portion between the antorbital vacuities, as far forward as the rather small premaxillæ.

"At the very front of the rostrum there is a rather small, but perfect, median, unpaired vacuity leading into a foramen in the middle of the palate below. I am at a loss to say what its real nature is. If not a median narial opening, I can not see why there should be a palatal opening below it. It is not for the passage of teeth, as in some labyrinthodonts. A median opening is not unknown among the Stegocephala. *Dasyceps*, from the Permian of Kenilworth, has a large, elongate opening between the nasals, and *Acanthostoma*, from the Rothliegendes, has a moderately large median vacuity between the large nasals and the premaxillæ.

"The greatly enlarged and elongated openings on the sides of the face in front of the orbits are, in part at least, merely antorbital vacuities; of this there can be no doubt. The anterior portions, however, seem to be the real nares, in position like those of *Eryops*, and opening into a vacuity at the outer side of the palatine and vomers of the palate. A flattened or concave bone is seen in the right fossa, directed obliquely backward. It may be a turbinated bone.

"The occipital condyles are parial, the gentle concave articular surfaces looking backward, a little downward, and toward each other. A specimen of *Eryops* in the collection shows, I think clearly, a transverse suture a little in front of these processes separating them from the part in front which I believe to be the basisphenoid, and just back of a pair of flattened or spoon-shaped processes, corresponding to the hypopophyses of the reptilian basisphenoid and occipital region. In front of these processes the bone is gently concave from side to side. In the middle in front there is a rounded heavy margin, which shows no traces of a bony prolongation, as in *Eryops*, into the median parasphenoid. On either side in front, the basisphenoid turns downward in a thickened process, quite as in *Eryops*, to articulate with the pterygoids. On either side, posteriorly, from the basioccipital processes a groove runs outward and upward, bounded in front

*"It has long been known that these so-called supraoccipitals of the stegocephalan and cotylosaurian skulls are not the real supraoccipital of the mammals and higher reptiles, but are membrane bones. Perhaps the best name that has yet been applied to them is that of Broom—the postparietals. In a later paper I shall figure both the cartilage supraoccipital and the membrane supraoccipitals in the same specimen, not even suturally united."

and behind by bars of bone. At about 30 mm. from the middle line, this groove turns at an acute angle forward nearly parallel to the median axis of the skull, to terminate at the outer end of the pterygoids and leading into the temporal vacuity. The bone containing this groove shows at its inner extremity a distinct suture separating it from the occipital and basisphenoid. It is doubtless, in part at least, the paroccipital.

"The pterygoid, from the basisphenoid articulation, turns transversely outward as a vertical plate, ending in a sutural articulation, just back of the orbit, with the anterior end of the bony ridge bounding what I believe to be the otic groove. The plate does not seem to reach quite to the roof of the skull in its middle part. The under margin of this plate is widened a little anteroposteriorly externally. Its outer extremity is lost, but it doubtless unites with the palatines at the outer side of the palatal surface, and probably sends back a posterior process at the sides to connect with a broken extremity of a flat bone on the inner side of the quadrate. The attachment of this bone, or of a separate transverse bone, is shown by a broken edge turned downward a little below the plane of the palatines to abut slightly against the upper inner margin of the mandible. There is no indication of a median parasphenoid prolongation in front of the basisphenoid, but a broken surface of a bone forming the brain case for the cerebrum, may perhaps represent what is left of the parasphenoid, which must in this case be far above the plane of the palatines and closely applied to the under side of the brain and its rhinencephalic anterior prolongation. The palatines, or the combined palatines and pterygoids, form a narrow horizontal shelf along each maxilla. The inner part of this shelf is thickened, so that its median border forms nearly a flat surface directed inward and downward, and separated by a depression or groove from the outer palatinal surface. Probably this portion represents the anterior prolongation of the pterygoids, but I can distinguish no trace of a suture between the two portions. The palatal shelf of the left side was crushed against the opposite side in the specimen, lying quite in contact nearly as far back as the orbits. There could not have been any median parasphenoid between the two parts, the angle anteriorly being acute and the palatines or vomers meeting and coming closely in contact anteriorly. The internal nares are oval vacuities situated nearly below the anterior part of the lateral facial vacuities. Just in front of the opening on each side and close to the margin of the mandible, as articulated, there is a large tooth, doubtless situated upon the vomer. There are four large teeth upon the palatines, also attached so that they come closely in contact with the inner side of the mandible in the closed mouth. These teeth are in two pairs. The first pair, of which the anterior one is the smaller, are situated a little in front of the orbit, the apex of the larger tooth reaching nearly to the lower border of the mandible. It has a length of 22 mm., with a width of 12 mm. at its base. The posterior pair, of nearly equal length, measuring about 12 mm. each, are also closely applied to the inner side of the mandible a little back of the middle of the orbit.

"*Teeth:* There are twenty-five or twenty-six teeth in each of the upper series, and about the same number in each mandible. Six of these, of rather small size, are attached to the premaxilla in front of the lateral narial opening. The longest measures 8 mm. The largest of the maxillary teeth are situated back of the middle of the narial vacuity, two of them measuring 14 and 15 mm. in length, by 5 mm. in diameter at their base.

"The mandible is rather slender, with a short symphysis, where the somewhat expanded bones form a shallow but short trough, the two together below gently convex from side to side. The lateral outlines of the mandibles from below have a gentle concavity near the middle, curving rather strongly inward behind. The inferior margin of the jaw turns upward behind rather abruptly, and is narrowed from side to side. The sutures of the mandible are not certainly distinguishable. Posteriorly the articular projects but very little beyond the quadrate.

"*Vertebræ:* The axis is much broader from side to side than the following vertebræ, and is very short antero-posteriorly. Its large, articular surfaces fit closely the condyles of the skull. Its posterior margin below is nearly parallel with the anterior. I can discover no indications of separated pleurocentra, though such may have existed. Its separated neurapophyses are vertical and slender, widely separated from each other above by the massive spine of the second vertebra. Above the middle of each neurapophysis there is a small, posterior zygapophysis for union with the second vertebra. The hypocentrum of the second vertebra is much smaller than the following ones, transversely oval in shape. There may be pleurocentra here also, but I can not distinguish them. The spine is very massive above, with strong rugosities posteriorly, broad from side to side, with the slender neurapophyses of the axis lying in contact with it in front. The hypocentra of the succeeding vertebræ are almost identical in size and shape, scarcely varying a millimeter in length or breadth, though those of the sacral region may be a little stouter. Where best preserved, they show a flattened surface on the under side separated by a ridge from the sides, though in others this flattened part seems to be merely a rounded keel. Many of the pleurocentra have been dislodged, but such as are in position in different parts of the column are alike in shape and in attachment, all rather smaller than the anterior or mesial ones of *Eryops*. The longer, neurapophysial attachment is with the succeeding arch. These attachments of the pleurocentra leave only a small surface on the hypocentrum for union with the arch, which, here as in *Eryops*, for the most part is more closely united with the pleurocentrum of the preceding vertebra than with that following the arch, to which it presumably belongs. Complete spines are present in several of the anterior and posterior vertebræ, but lack their distal extremities in most of the others. As is the case with the hypocentra and pleurocentra, they are all nearly alike throughout in thickness and length. They are a little compressed from side to side, and slightly thickened at the upper extremity. Anteriorly the spines are nearly vertical, but posteriorly they are slightly inclined backward. The transverse processes, springing from the arch, are also, so far as can be determined, nearly alike throughout the presacral series. They are stout, slightly compressed vertically, and are directed nearly straight outward, or a little backward. The zygapophyses are rather better developed than in *Eryops*, and are not placed so closely together, their articular facets at an angle of about forty-five degrees. The transverse process for the sacral rib is very stout and heavy, with its large articular facet directed outward and downward. There is but one true sacral vertebra, though the transverse processes of the vertebræ immediately preceding or following the sacral are heavier than elsewhere. Altogether the vertebræ of *Trematops* are very much like those of *Eryops*, the pleurocentra anteriorly somewhat smaller, the transverse processes somewhat

longer and stouter, and the zygapophyses a little better developed. Of the caudals, save the two connected with the sacral vertebræ, only one small block of matrix containing several more or less confused bones of the distal part of the series is preserved. The chevrons are stout and short, united above in a heavy hypocentral mass, which is excavated in its middle for the notochord. In front of one of the preserved chevrons there is a pleurocentrum which seems to have separated the hypocentra ventrally.

"The ribs are everywhere short. For the first nine or ten vertebræ they are much dilated, both proximally and distally, with the distal portion twisted somewhat from the plane of the proximal. They have a slight but distinct curvature. In the region of the fifteenth vertebra the ribs are much smaller, with the proximal portion less dilated, and with a longer, rounded shaft. The first rib preserved in the matrix has its head closely applied to the side of the second vertebra. The attachment of the ribs, at least anteriorly, was to both the transverse process of the neurocentrum and the pleurocentrum or hypocentrum, though no articular face is visible. The sacral rib is quite like that of *Eryops*. It has a broad, stout, proximal portion articulating chiefly with the transverse process, but also below and in front with the hypocentrum or region between the hypocentrum and pleurocentrum; the distal part is much flattened and expanded, and is curved downward.

"*Pectoral girdle and extremity:* Scapula-coracoid. The right side of the pectoral girdle was found inclosed in the matrix close to the skull, lying on the sides of the anterior vertebræ. The preserved parts are very complete. Some fragments of the border of the coracoid, and the tip of the clavicle only are missing. The united bone, on the whole, resembles that of *Eryops*, save especially in the absence of the cleithrum, which is large and stout and closely applied to the front border of the scapula in *Eryops*. The scapula is much expanded above, and is flattened, a little thickened posteriorly, the planes of its outer and inner surfaces directed a little inward anteriorly. The scapula narrows rapidly to within a short distance of the glenoid fossa, and then is widely expanded anteroposteriorly for the coracoids. That portion corresponding to the procoracoid of the allied reptiles is a little thickened, nearly flat, and directed somewhat toward the visceral side. The lower anterior angle is nearly rectangular, and the mesial border of the whole bone is gently convex in outline and is somewhat thinned. Posteriorly the rather narrow coracoid projects strongly backward, its narrowed extremity thickened and strongly curved toward the visceral side. The deep glenoid cavity is directed upward, backward, and outward. Above, the thickened hind border of the scapula divides, inclosing between its two branches a rather deep, non-articular fossa. The anterior or external branch continues downward in the same plane and direction as the scapular border, ending in a subtriangular, articular facet looking backward and outward. The end of the humerus lay in immediate apposition with this facet. The posterior continuation of the scapular border, the thicker of the two, curves inward and backward, in a strong, nearly semicircular sweep to near the extremity of the coracoid. Between these two divergent borders there is a deep cavity or fossa, evidently no part of the real glenoid fossa, pierced by a large foramen or fenestra at its bottom. Just below the lesser ridge which bounds this fossa posteriorly from the glenoid cavity, running from the internal angle of the humeral facet upward and backward, and near its middle part, there is a second foramen, which opens on the convex surface

of the inner side of the bone. A third foramen is seen below the humeral facet, opening on the inner side at the lower end of the vertical flexure. This must be the true supracoracoid foramen, through which the scapula-procoracoid suture doubtless passes. The true glenoid fossa is limited below posteriorly by a strong declivity. The inner surface of the scapula above, like the exterior, is nearly flat, the lower surface convex in front. Just back of the glenoid cavity and corresponding to the vertical margin of the outer side, the bone on the inner side turns abruptly outward, save on the lowermost portion, bounding in front a posterior cavity into which opens the supraglenoid and the supracoracoid foramina, above and below, as shown by the arrows in the figure. In front of the border, the surface of the bone is strongly convex from above downward, and somewhat so from side to side. This surface is pierced near its middle by the glenoid foramen.

"No sutures are visible distinguishing the bone into its three elements. As regards the cleithrum, there is a total absence of all indications of such a bone as occurs in *Eryops*, either on the upper or anterior border.

"*Clavicle and interclavicle:* The right clavicle was found in the matrix nearly in its anatomical position, its upper end only gone. It is very small for an amphibian, and has lost every trace of the pittings so characteristic of the stegocephalan clavicles on its outer surface, though not unlike the clavicles of *Eryops*. (See Williston, Kansas University Quarterly, VIII, 185, plate XXIX, fig. 2.) The clavicle is bent near the middle nearly at a right angle, and somewhat twisted. The proximal part, underlying the interclavicle, is but moderately expanded—less so, in fact, than in the contemporary reptiles, and not twice the width of the distal part. Its anterior border is thickened, its posterior, somewhat everted, portion is thin. The scapular extremity is lost, but there is some, though doubtful, evidence of the possession of a small cleithrum, shown by a fragment of a small bone apparently attached to it. The greater part of the interclavicle is present in the specimen, lying on the under side of the procoracoid angle of the scapular bone. The bone is flattened and expanded transversely, with a short lateral projection on each side, and a thin but broad anterior margin. In the middle, posteriorly, the bone is slightly thickened, but there was no median, posterior elongation, as in the reptiles. The interclavicle is remarkable for its small size, and thinness, as well as for the entire absence of external pittings. As a whole, the clavicular, as well as the scapular girdle, is markedly reptilian in character, far more so than in any other known amphibian.

"*Humerus:* The humerus resembles not a little that of *Eryops*, a figure of which, more reduced, I have given for comparison, although a little more slender, as are, indeed, all the bones of the extremities. The two expanded extremities are twisted at an angle of about sixty degrees, the shaft between them abruptly and much constricted, about 8 by 10 mm. in diameter. The proximal anterior face is somewhat concave. The distal portion has a large rounded radial convexity on its outer side, above which, separated by a groove at the outer side, is a small process, evidently quite like that of *Eryops*. The inner condyle is somewhat thickened; the entepicondylar margin is convex from above downward, but wholly without an epicondylar foramen, such as is present in the related genus *Acheloma* Cope.*

*This opening has been shown to be accidental and not a foramen.—E. C. C.

"The two extremities of the right ulna were found free in the wash, distinguished from the reptilian ulna found with the specimen by their much smaller size and the less produced olecranon. The proximal portion is convex on the inner side, thinned above and below. The outer side is concave for the radius, with the humeral articular surface, or sigmoid cavity, showing more from that side. The olecranon is rugose. The distal extremity is but slightly expanded, a little thickened in the middle at the end, gently convex on the dorsal, and concave on the palmar surface.

"The extremities of what I believe to be the radius are among the fragments recovered in the wash, but the present impossibility of distinguishing them from the reptilian remains renders their description inadvisable. I have outlined the bone in the restoration from *Eryops*.

"A mass of matrix containing nine carpal bones united in their proper relations was secured. Their distinction from the reptilian specimen is assured by their smaller size, and the determination of the carpal bones in that specimen. Their relative size and position, as I determine them, will be seen in the restoration. It is evident that two of the proximal bones are missing, and they are shown in shaded outlines in the figure.

"*Pelvic girdle and extremity:* The left ilium was preserved, attached to the sacral vertebra and rib, nearly or quite in normal position, but considerably eroded on its outer surface. The acetabular portion of the same side, found loose, shows also considerable erosion of the surface, and the precise connection with the ilium worn off; the symphysial portion, also, of both ischium and pubis is wanting. The ilium resembles somewhat that part in *Eryops*, but is broader, less elongate, and thinner. The acetabular part is quite similar to that of *Eryops*, and it is quite probable that the missing portion below will be found also like that of *Eryops*. The acetabulum is large and shallow, with a thickened rim in front, a rounded protuberance at the upper part, and a thickened margin at the lower posterior part. The pubic foramen below the anterior part of the acetabulum opens on the inner side toward the front margin.

"*Femur:* The left hind leg is preserved almost completely, and with but little disturbance of its parts, lying partly upon, partly at the right side of the vertebral column, its ventral side uppermost, the femur much flexed and inclined over the vertebræ to meet the acetabulum, which was lying nearly horizontally. The femur resembles in miniature that of *Eryops*. Its proximal extremity is thickened, transversely convex above, much thickened on the inner side, less so on the outer, and with a shallow fossa behind, externally. The shaft is much narrowed from side to side at the lower third. The 'lesser trochanter' is robust, beginning about one-third the length of the bone; its face is oval in outline, with a longitudinal groove, and is directed proximally and ventrally. The 'linea aspera' continues the trochanter as a high, thin longitudinal crest, curved somewhat outward, to end near the beginning of the last fourth of the bone, in the upper part of the popliteal surface, about midway between the lateral margins. The distal extremity of the femur is expanded to the full width of the proximal extremity, chiefly on the inner side, the internal border of the bone forming a deep concavity above, while the external border of the bone is gently concave on the middle two-fourths, the first and last fourths gently convex in outline. The distal border of the inner condyle is nearly transverse and straight, thickened internally; the external condyle is narrow, and greatly

expanded anteroposteriorly, so that the distal articular surface somewhat resembles an italic letter *L*, with the intercondylar groove in front deep, the popliteal groove shallow. In front, the outer border is convex to the articular surface for the fibula, and the articular surface as a whole is directed ventrad at an angle of about forty-five degrees from the long axis of the femur, and also outward at an angle of about twenty degrees; the articular surface also extends proximad on the ventral side so as to permit a considerable degree of flexion, while complete extension would have been impossible. The considerable depth of the pelvic symphysis raised the acetabular surface some distance from the ground, and doubtless the knee was constantly flexed to a considerable extent.

"The tibia is preserved in the matrix in articulation with both the femur and tarsus, but rotated somewhat upon its outer side. Its proximal extremity is much expanded, anteroposteriorly, and also somewhat from side to side. Its articular surface for the femur is slightly concave, sloping obliquely backward and outward from the long axis. Its proximal part in front is broad for the insertion of the stout muscles of the intercondylar groove, while a large surface posteriorly also gave insertion to the flexor muscles. The middle of the shaft of the bone is slender, and nearly circular in cross-section, from which place the bone becomes gradually broader to the distal end, which is thickened and broader from side to side than from before back. The outer border of the bone, as a whole, is nearly straight, or gently concave; the inner border is deeply concave.

"As already stated, the fibula was dislodged from its position. Lying close by the inner side of the tibia is a flattened bone, imperfect at one side, which is evidently the distal extremity of a fibula. The part preserved is remarkably broad, much thinner on its outer side, thickened, shaft-like on the inner, where it is broken off. Distally it shows two thickened, apparently articular borders separated by a thinner, non-articular margin.

"The tarsus and foot lie almost perfectly in position, the tibiale slightly turned outward by the rotation of the tibia, and the fifth toe partially turned under the fourth and third. Lying as they do upon the sides of the fourteenth, fifteenth, and sixteenth vertebræ, the bones are somewhat uneven, because of the rugosities. There are twelve tarsal bones, three in the proximal, four in the middle, and five in the distal row, a number found by Baur in *Archegosaurus*, but otherwise unknown among air-breathing vertebrates. Of the proximal row, the tibiale is elongate, a little broader proximally, with a thickened, rounded internal margin, articulating proximally with the tibia, distally with the first centrale, and internally with the second and third centralia. The intermedium is large, with a thickened, oblique face for union with the fibula proximally, a free rounded border opposite the distal part of the tibia, articulating distally with the large centrale, and externally with the fibulare, leaving, however, a small opening for the passage of vessels. The fibulare is elongate anteroposteriorly, and is rather broad; it articulates proximally, on the upper side, with the fibula, internally, above, with the intermedium, distally with the fourth and fifth distalia, and between them and the intermedium with the large centrale. The proximal centrale is one of the largest bones of the tarsus; it is somewhat broader on the inner than on the outer end, articulating proximally with the intermedium, internally with the tibiale, externally with the fibulare, and distally with the two outer centralia. The innermost

of these is the smallest, articulating between the tibiale and the first distal, and, on the outer side, with another centrale. This is an unusual position for a centrale, and I have endeavored to find in the small bone some evidence of extraneous origin, but am quite convinced that it really belongs in this place, as otherwise the space it occupies must have been unossified. The median distal centrale is the largest of the three distal centralia, and is nearly square in outline; it articulates proximally with the tibiale and proximal centrale, on either side with a centrale, and distally with the second distal. Of the distalia, the second is the largest and the fifth is the smallest, the third and fourth smaller than the second. Each distal supports its own digit exclusively.

"The digits are, it is seen by the figure and the restoration, very short and heavy. The first metatarsal is very characteristic in its broad and short form, resembling more a proximal phalanx, broadly expanded proximally and much constricted in the middle. At its distal extremity there is a fragment of the first phalanx in articulation, the remainder being lost. The width of this fragment would indicate the possibility of a second phalanx of very small size. The second metatarsal is much longer than the first, its proximal extremity less expanded. Its first phalanx is short and expanded, much shorter and smaller than the corresponding phalanx of the third finger. At its distal extremity is preserved the proximal extremity of a very small second phalanx, and there was probably no more present in the living animal. The third metatarsal is much longer than the second, with its proximal extremity more oblique to its long axis. Its distal extremity is quite on a line with the distal extremity of the second metatarsal. The first phalanx is stouter and longer than the first phalanx of the second digit, and a trifle smaller than that of the fourth, its greatest width about equal to two-thirds its length. The second phalanx, preserved entire, is much smaller than the first, and is very short and broad, its width equal to its length; it is but little constricted at its middle. A proximal half or end of a minute third phalanx is also present. It was somewhat pointed in shape, but by no means a claw. The fourth metatarsal is much like the third and of about the same length, its proximal extremity yet more oblique. Its proximal phalanx is a little longer than the first of the third digit, its distal extremity surpassing a little the distal extremity of the third metatarsal. The second phalanx is a little longer but no broader than the second of the third toe. Its third phalanx is about two-thirds the length of the second, but is much narrower distally. The basal part of the fourth phalanx, a very small bone, is articulated with the third, and it is very evident that it was the terminal one, and was very small and in no sense a claw. The fifth toe is slender, and was divaricated in life. In the specimen, while still retaining its articulation with the tarsus, it is turned across the fourth and third metatarsals. Its metatarsal is much narrower, and not more than three-fourths the length of the fourth. Its first phalanx, likewise slender, is about the length of the first phalanx of the second toe, but is much narrower. The second phalanx, much shorter, is narrowed distally, but with a minute terminal knob or expansion. Possibly an ossicle not larger than a pin-head may have articulated here, but probably not.

"The actual phalangeal formula of the foot as preserved is, it is seen, 1, 2, 3, 4, 2. It is possible, though not very probable, that the first, second, and fifth digits may have had a minute ossicle at the extremity of each,

making the formula, 2, 3, 3, 4, 3. The feet were clawless, the toes ending rather bluntly. The foot as a whole, it is seen, is remarkable for its broad, short form, and, because of the relatively large size of the tarsus, it must have been very flexible. The absence of true claws, such as occur in some of the Cotylosauria at least, and the Pelycosauria, is what we would expect. The relatively short legs and broad feet were used exclusively in locomotion. The front feet could not have been extended nearly as far forward as the mouth and could have been of no possible use in seizing or holding the animal's prey; and it is quite certain that the creatures did not need claws for locomotion over soft ground.

"In the restoration the front toes have been copied from the hind ones, and it is not at all probable that there could have been much difference between them. That there were five fingers is shown conclusively, not only from the carpus, but also from the front foot of *Eryops*, as figured by Cope, a form which, in its skeletal structure, is closely allied to *Trematops*. The radius also is given from the same figure by Cope. The fibula is in part conjectural, as is also the length of the tail. It is possible that the head was set even more closely upon the shoulders.

"From the absence of every indication in the matrix of a dermal armor, it is quite probable that the creature had a bare skin; and the absence of claws and its short legs and feet indicate also that the animal lived not on high, dry lands, but about the mud shores and in the water. The entire absence of a neck, which is characteristic of all the lower vertebrates of the Texas Permian, the large, ungainly but flattened head, the short body and tail, and short, rather stout limbs, all must have given to the creature a very bizarre aspect.

"The distinction of *Trematops* from other genera of the rhachitomous amphibians described from Texas seems certain. Its relationship with *Eryops* is evident, but, aside from its smaller size and greater slenderness, the structure of the head separates them widely. From *Acheloma*, which I at first thought might be the same, there seem to be marked differences. Cope's description of *Acheloma* leaves certain parts in doubt, parts of much importance in the discrimination of the two genera, especially the size and shape of the vacuities. He describes the premaxillary teeth as five in number and of large size, whereas in *Trematops* they are six in number and are among the smallest of the whole series. He also states that the humerus of *Acheloma*, a very remarkable thing for an amphibian, has an entepicondylar foramen, whereas there is no trace of such in the present form. Dr. Matthew of the American Museum has very kindly compared the type of *Acheloma*, at my request, and confirms these details, and also informs me that the skull is different in shape from the figure sent him of *Trematops*. I have no hesitation, hence, in giving to the present specimen the generic name *Trematops*, chosen in reference to the numerous vacuities of the upper side of the skull."

Family LYSOROPHIDÆ Williston.

Genus LYSOROPHUS Cope (page 68).

Characteristic specimens: Skulls in the Am. Mus. Nat. Hist. Nos. 4696 and 4701; in the University of Chicago, and in the University at Munich. The type in the University of Chicago, Nos. 6526 and 6527, 6528. Numerous specimens of vertebræ in both these institutions.

In all of the enormously abundant material which has been collected in Texas, but one species of this genus has been recognized, and this species is not distinct from the one described by Cope from Vermilion County, Illinois. The following description is made up from the writings of Cope, Broili, Williston, and Case.

The *skull* is small, from 1.5 to 2 centimeters in length and is elongate oval in form. It has no parietal foramen and no temporal fossæ. The orbits are lateral and without inferior border. The anterior nares are terminal and near the outer edge of the skull. The surface of the skull is smooth,

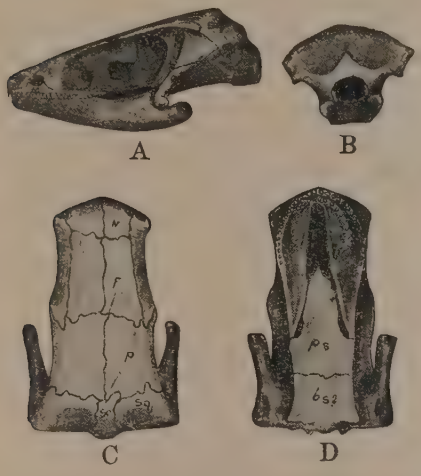

Fig. 47.—*L. tricarinatus.* Nos. 4696–4701 Am. Mus. × 2. Restoration of skull.

A, Left; B, Posterior surface; C, Superior surface; D, Inferior surface. Lettering as usual.

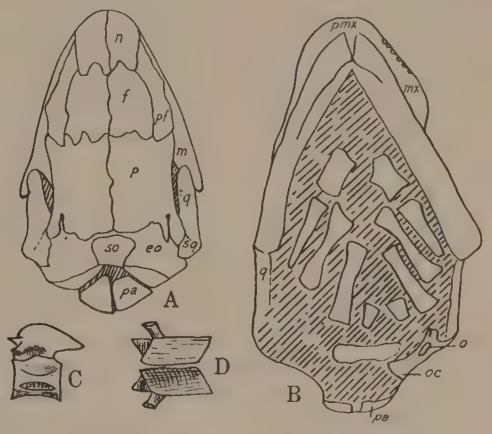

Fig. 48.—*L. tricarinatus.* Univ. of Chicago. × 3 circa.

A. After Williston. Upper view of skull, showing sutures. Lettering as usual.

B. Same. Lower view of skull, showing branchial bones. *o*, otic opening; *oc*, occipital condyle; *pa*, neural arches of first vertebra.

C. Same. × ⅔. After Broili. Lateral view of a mid-dorsal vertebra.

D. Same. Neural spine from above, showing permanent separation of the two halves.

without sculpture or rugosities. The various investigators of *Lysorophus* seem to be in complete accord as to the position and shape of the bones of the skull, but differ materially in their interpretation.

The *upper surface* is composed largely of three pairs of bones, the nasals, frontals, and parietals.

The *nasals* are large, paired elements extending to the anterior end of the skull; the premaxillaries have not been made out, and were evidently very small. The nares lie outside of the nasals and are terminal.

The *frontals* are nearly rectangular and extend back as far as the anterior edge of the orbit.

On either side of the skull, parallel to the frontals and nasals, are elements running from the anterior edge of the orbit to the posterior edge of the nasals; a descending process, near the anterior end, forms the posterior edge of the nares and joins the maxillary below. These bones form the side of the facial region and have been called *lachrymals* (Case) and *prefrontals* (Williston).

The *maxillaries* are short and very slender. They form the lower border of the nares and send a long splint back to a point below the middle of the orbit.

The *parietals* are large plates forming the whole interorbital surface of the skull, and are strongly convex from side to side. There is no trace of a parietal foramen.

The *supraoccipital* is a single median plate which extends downward on the posterior surface to form the upper edge of the foramen magnum.

On either side of the supraoccipital plate are large elements forming the posterior angles of the skull; these were called *squamosals* by Case and *epiotics* by Williston. Their homology seems uncertain.

From the lower side of these elements, a projection forward carries on its lower end the articulation for the lower jaw; it is certain that the lower end represents the *quadrate*. The upper portion may or may not be distinct; a partial suture was noted by both Williston and Case. The upper part, called by Williston the squamosal, corresponds almost exactly to the part called tympanic (Hoffmann) or paraquadrate (Gaup). The lower, quadrate end of this composite bone becomes very slender and rod-like.

The lower surface: A large flat bone forms the posterior surface of the basicranium; this is considered to be a *basisphenoid;* anteriorly it is joined by an equally broad element which terminates in a point anteriorly, the *parasphenoid*.

Anterior to the parasphenoid the separate elements can not be made out. The teeth extend in an unbroken curve around the anterior edge of the skull, and a second line of palatine (?) teeth within this follows nearly the same curve. There is a great median, palatine vacuity.

Broili reported the occurrence of gular plates lying between the lower jaws, but Williston has given reasons for believing that these are the displaced elements of a proatlas.

Posterior surface: This is completely closed. There are distinct, exoccipital condyles (Williston and Case); Broili believes that there is a single tripartite condyle, the lower portion formed by the basioccipital bone. This he reports on the evidence of several specimens; Williston and Case, working independently, with separate series of skulls, are of the opinion that the condyles are paired and formed by the exoccipitals. Broili's criticism of Case's drawings showing the condyles does not take into account that the condyles slant inward and upward; the greatest distance between the condyles shown in the posterior view of the skull is greater than that between the portions of the condyles shown in the lower view, but it is the upper ends of the condyles which show in the lower view, and the two drawings coincide exactly.

The *lower jaw* is about two-thirds the length of the skull and is very wide in the articular region. The angle projects considerably beyond the quadrate. The dentary carries small conical teeth similar to those of the maxillary.

There are four pairs of *branchial bones* in one specimen described by Williston (69). "The outer pair, lying close to the inner margin of the mandibles, have the posterior end thickened and recurved, hook-like, to abut against or approach the hind side of the quadrate. I would take them to be ceratobranchials, save for the fact that a pair of nearly square bones very clearly articulate with the anterior ends, which must be ceratobranchials. To the inner side and progressively more posterior, lying symmetrically, are three pairs of epibranchials, the inner and hindmost represented in the specimen only by their anterior ends, the posterior portion being broken off with the atlas. The two outer pairs, at least, are thickened and truncate at each end, and are partly hollowed or cancellated, like all other bones of the skeleton. The first of these pairs also seems to have a thickened and recurved posterior extremity."

The vertebral column: Just over the occipital condyle are two small plates, which probably represent a proatlas. There is no distinct atlas or axis, and the vertebræ of the column are all similar. The centrum is perforate, and the cavity is widely open, so that the notochord was very little constricted. The sides are marked by deep pits, which divide the lower surface of the centrum into three ridges, hence the name of the species. The neural arch is free from the centrum and the two halves are separate. The zygapophyses are nearly horizontal. There is no trace of intercentra.

The *ribs* are single-headed, rather long, and proportionately stout. They are frequently broken at the proximal end and present the appearance of having been anchylosed to the centrum and broken off.

Williston reported finding small limb bones among the specimens of *Lysorophus*, but it is very uncertain whether these belong to *Lysorophus;* at least four genera have been found in the same beds, *Gymnarthrus*, *Cardiocephalus*, young *Diplocaulus*, *Lysorophus*. Thousands of series of *Lysorophus* vertebræ have been found with very perfectly preserved ribs and centra, but without any trace of limbs associated. It seems, with all of the suggestions of a snake-like body, that it is less likely that these limb bones belonged with *Lysorophus* than with some of the other forms.

The position of *Lysorophus* is not certain. That it is an amphibian seems well established. Broili's interpretation of the condyle as single is certainly not borne out by numerous other specimens. The same may be said for the basicranial region; it is certain that the broad flat plate can not be reckoned as a basioccipital element; parts taken for this in several specimens have proven to be fragments of the proatlas or first vertebra. In addition, Williston cites the tricarinate vertebræ, the sutural division of the neural arch, and the neuro-central attachment of the ribs as distinctly amphibian.

It is not so apparent that the *Lysorophus* was a Urodele of the group *Ichthyoidea*, as declared by Williston. The apparently limbless condition and the probable position of the eyes far forward in the orbital spaces suggest some affinity with the limbless amphibians. The singular fact that the specimens are always found in a more or less tightly rolled up condition, led the late Dr. Baur to suggest that these were embryonic forms, but the enormous numbers and well-ossified condition negative the idea, It is more probable that they were, as Williston suggests, naked-skinned, mud-burrowing creatures, that met their death by suffocation in large, shallow pools, which were in process of gradual desiccation. This would

account for the accumulation of large numbers of animals in small areas, and it would also account for the attitude in which they are found.

Measurements.	MM
Length of a skull on median line	20.8
Length of a second skull, same	19.5
An average vertebra	
Height from bottom of centrum to top of neural arch	7
Greatest length of centrum	5
Greatest length of neural arch	7

Genus GYMNARTHRUS Case (p. 69).

Gymnarthrus willoughbyi Case (p. 69).

Characteristic specimens: The type and paratype Nos. 4892 and 4763 Am. Mus. Nat. Hist.

The type skull is small, total length slightly over 16 mm., but, as the premaxillaries are imperfect, it is impossible to give the exact length. At first sight the skull resembles closely those described by Cope as *Pariotichus* and *Lysorophus*, but it is radically different in the postorbital region. The postorbital portion of the roof of the skull has been cut away from the lower edge in the manner of some turtles, until the quadratojugal is gone, the prosquamosal doubtfully present, and the quadrate fully exposed and perhaps movable. The posterior portion of the skull is roofed over and there is no suggestion of temporal openings. The quadrate is elongate and of peculiar shape (see fig. 49); it articulates with the squamosal above and seemingly with the occipital (supraoccipital + paroccipital + exoccipital) plate behind. The posterior surface is somewhat injured and it is impossible

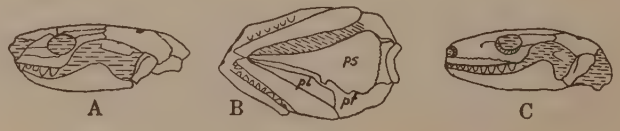

FIG. 49.

A. *G. willoughbyi.* × ⅔. No. 4763 Am. Mus. Lateral view of skull.
B. Lower view of skull. Same specimen.
C. *G. willoughbyi.* Lateral view of skull. No. 4892 Am. Mus. × ⅔.

to make out the form and relations of the various bones. The relations of the bones of the upper surface are shown in fig. 16. The premaxillaries were apparently large and sent back a process between the nares to meet the nasals. The anterior nares were of good size and terminal in position. The maxillary carries nine teeth; the posterior is small, the penultimate the largest; from this point they diminish regularly toward the anterior end. There are no tusks or enlarged teeth on the premaxillaries, the incisor teeth sharing in the regular diminution in size toward the anterior end of the skull. The three posterior teeth are the largest and have a greater anteroposterior diameter than transverse. There is no cutting edge on the anteroposterior faces.

On the lower surface the basioccipital occupies a small space at the rear; the basisphenoid is a large flat plate and unites directly with a strong parasphenoid process. At the anterior end the parasphenoid meets two diverging plates, which are apparently the palatines, but in large part they are covered by the lower jaws. The lower edge of the pterygoids can be

made out as a thin line in the matrix, which fills the back part of the skull; its relations to the basisphenoid and quadrate are normal.

The lower jaws lie in position between the upper jaws and the teeth can not be seen. The articular region is low, and just anterior to this the upper edge rises in a prominent coronoid process. The different bones of the jaws can not be made out, but it is apparent that the dentary takes part in the symphysis.

The paratype confirms the points made out in the type. It shows the pterygoids as broad plates, approaching each other in the middle line. If there were any teeth on the pterygoids, they are too small to be seen in the present condition of the specimens. Certain small openings, anterior to the orbit in the type specimen, were considered as antorbital openings, but, as these do not appear in the more perfect paratype, they are probably accidental breaks. The type specimens of *Cardiocephalus* are not well preserved and it was impossible to recognize the relationship of this genus to *Gymnarthrus* from the description, but a direct comparison makes it very apparent. *Cardiocephalus* has, in both specimens, grooves lying on the inner side of the orbits, which seem to be natural and not the result of pressure; also, the pineal foramen is extremely small or absent; because of these structures, which are absent in *Gymnarthrus*, the latter is retained in a separate genus, although it is recognized that when more than the skull is known the two may have to be united.

Gymnarthrus was originally regarded as a reptile, but it may almost as readily be placed among the *Amphibia;* because of its resemblance to *Cardiocephalus* it is here placed provisionally in the latter class.

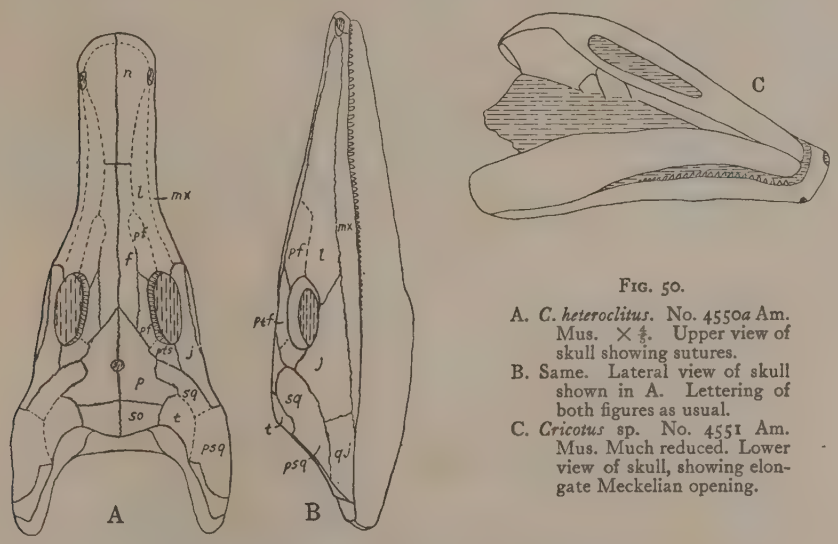

Fig. 50.

A. *C. heteroclitus*. No. 4550*a* Am. Mus. × ⅔. Upper view of skull showing sutures.
B. Same. Lateral view of skull shown in A. Lettering of both figures as usual.
C. *Cricotus* sp. No. 4551 Am. Mus. Much reduced. Lower view of skull, showing elongate Meckelian opening.

Genus CRICOTUS Cope (p. 72). (Plates 24, 25.)

Characteristic specimens: Nos. 4550, 4550*a*, 4551, and 4552 Am. Mus. Nat. Hist. Cope Coll.

The best specimens of this genus preserved are Nos. 4550 and 4550*a*, the type of *C. crassidiscus*. A large skull, No. 4551, shows little more than the general form; the sculpture and sutures can not be made out.

Figure 50, A and B, gives a restoration of a small skull No. 4550*a*, with such sutures as are certain. The whole skull is slender and elongate, with small, subequal, conical teeth showing along the edge of the maxillaries. The extremity of the snout is broken away just posterior to the nostrils, but the larger skull shows that the nostrils were nearly terminal. The orbits and nares looked largely upward. The sculpture, so far as can be seen, consists of small pits and rugosities. The supraoccipital plates are small and short, as are the tabulare. There are no prominent posterior angles on the tabulare. It is not possible to detect a suture between the postorbital and postfrontal, and the ends of these bones extend nearly to the anterior edge of the orbit. The lower jaw is very deep posterior to the middle; the angle does not project beyond the quadrate region. On the inner side there is a narrow, elongate opening into the Meckelian cavity.

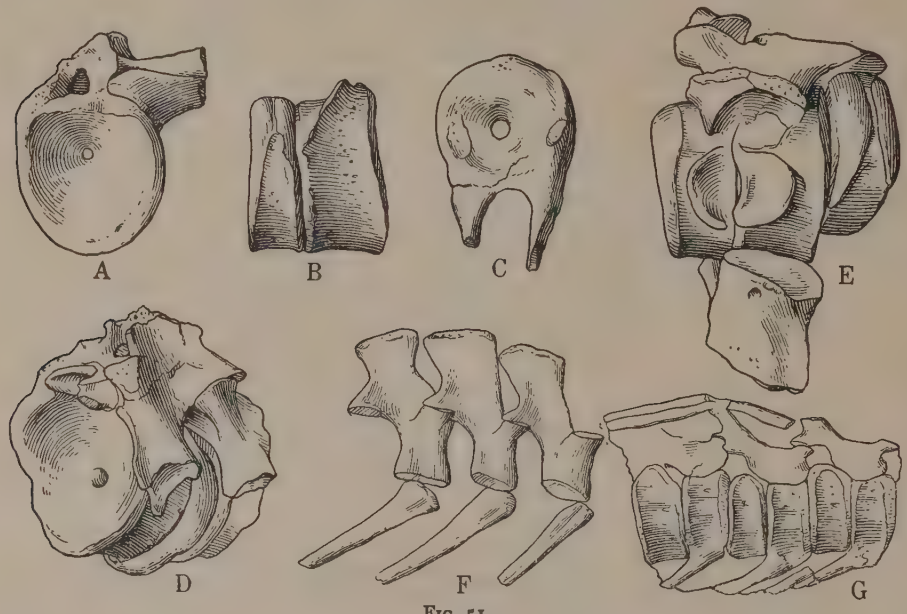

FIG. 51.

A. *C. hypantricus*. No. 4552 Am. Mus. × ⅔. Anterior view of a dorsal vertebra.
B. Same. Lateral view of a dorsal intercentrum and pleurocentrum with neural arch detached.
C. Same. A caudal intercentrum with attached chevron.
D. Same. Anterior view of a dorsal pleurocentrum, showing hypantropophyses on sides of neural canal.
E. Same. Sacral pleurocentrum and intercentrum, showing facets for rib head.
F. *C. heteroclitus*. No. 4550*a* Am. Mus. × ⅔. Neural arches and transverse processes of three dorsal vertebræ with rib heads.
G. Same. Several caudal vertebræ showing elongate neural spines, and relation of neural arches and chevrons to pleurocentra and intercentra.

The vertebral column of the most complete specimen shows thirty-seven presacral vertebræ, but this is not the complete number, as there are at least two missing from the anterior end. Even the most anterior vertebræ are embolomerous. The presacrals are all of similar form; the intercentra and centra are as described by Cope (see the original description). The neural arches are free from the centra; the spines are low, with considerable fore-and-aft extent; the zygapophyses are horizontal; there are well-developed transverse processes, to which are attached fairly long, slightly curved,

single-headed ribs. The number of caudals is uncertain, but the tail was certainly very long, longer than the presacral portion of the body. As mounted in the American Museum, one specimen, No. 4550, has the tail sufficiently long to include forty-five or more complete vertebræ; this is perhaps too long. The pieces of the tail preserved do not fit and are arranged according to size. The neural arches of the caudal vertebræ are free and rest almost equally on centra and intercentra. The arches are elongated; the spines rise from far back and are very long. One nearly perfect spine reaches back over the second succeeding vertebra, measuring 65 mm. The chevrons are fused to the intercentra, the ends are broken so that the complete length can not be given; one nearly complete chevron, from a point near the end of series, measured 33.5 mm. Free ribs occur on the anterior caudals.

The interclavicle is rhomboid, with a sharp point to the rear; the clavicles are represented by the anterior ends only; these overlap the interclavicle below; neither the clavicles nor the interclavicle show a determinable sculpture. There is a slender cleithrum with pointed anterior and clavate posterior ends. The scapula can not be made out.

The abdominal armature of scales (plate 25) underlies the clavicular arch, covering the posterior end of the clavicle and interclavicle. This is composed of rhomboidal scales overlapping from before backward, and arranged in parallel series on each side. There are six to eight scales in each lateral series. The rows of the two sides are inclined forward and inward over the greater portion of the abdomen and form a chevron pattern with the apex forward; but just posterior to the pectoral arch the pattern is reversed, and the chevrons anterior to this point to the rear. There is not a single V-shaped scale in the middle, but the scales of opposite sides overlap alternately.

The pelvis is represented by the ilium and a fragment of the ischium. The ilium is much more reptilian in appearance than in most of the amphibia; the crest has a considerable posterior prolongation to the rear; the lower end is wide, showing the presence of a broad ischium and pubis.

A *femur* attached to specimen No. 4550 is quite similar to that of *Eryops* in general form, but lacks the prominent, thin keel on the anterior face.

Measurements.

	MM
Specimen No. 4550*a*, as mounted:	
From tip of nose to end of sacrals	820
From sacrals to tip of tail	720
Length of skull from anterior end of nose to middle of back of skull	150
Back edge of skull to front of orbit	78
Interorbital width	21
Back edge of skull to anterior edge of parietal foramen	22
Specimen No. 4550, as mounted:	
From anterior end of clavicle to tip of tail	1048.5
Length of ventral armor	675
Length of a femur	70.5
A large skull No. 4551:	
Length from tip of nose to middle of posterior edge	238
Middle of posterior edge to anterior edge of orbit	81
Interorbital width	34
Posterior edge to anterior edge of parietal foramen	38

The foregoing description, with the original description quoted, gives about all we know of this creature. It is certain that it was an aquatic form with a very slender body, short legs, and a powerful tail. It was probably the most active of the amphibia of its time, rivaling in its speed and aggressiveness the contemporary *Reptilia*. Its form and general adaptations suggest that it occupied a position in the animal world similar to that of the more slender and active *Crocodilia* to-day.

Moody has recently (**62**) noted the occurrence of an embolomerous form in the Mazon Creek deposits. He regards it as related to *Cricotus* and belonging in the family *Cricotidæ*. "It differs from *Cricotus*, however, in the form of the centrum, and the relatively greater length of the component elements. The notochordal canal is widely open."

TWO NEW INSECTS FROM THE PERMIAN OF TEXAS

By

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TWO NEW INSECTS FROM THE PERMIAN OF TEXAS.

The specimens submitted to me by Professor Case consist of two detached front wings of cockroaches; two species being represented by the two specimens. The insects are preserved in a thin stratum of impure limestone. This limestone, according to Professor Case, lies directly upon a blue-clay stratum in which is found conifers and some fresh-water forms, probably *Estheria*. The two specimens derive an added interest from the fact that they are the first insects obtained from the Texas Permian. The character of the limestone in which they are preserved is not unlike that from which insects have been obtained in the Kansas Permian,* and it may be confidently expected that additional material will ultimately be obtained from the Texas deposits. The genus *Etoblattina* to which the two species are provisionally referred is common both to the Upper Coal Measures and to the Permian. The two species are new.

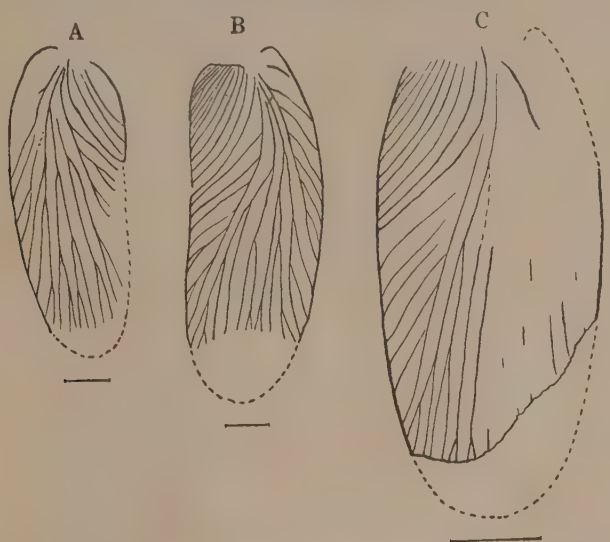

FIG. 52.—Wings of fossil cockroaches.
A. *Etoblattina texana* sp. nov.
B. *Etoblattina permiana* Sellards. A specimen from the Permian of Kansas, inserted for comparison.
C. *Etoblattina* (?) *robusta* sp. nov.
The line beneath each wing indicates three-fourths the breadth of wing measured across anal area.

Etoblattina texana sp. nov. (Text fig. 52 A.)

Small cockroaches. Tegmina slender, almost three times as long as broad. Subcostal area short. Radial area strongly developed, its branches occupying a part of the apex of the wing. The radius divides first near the termination of the basal fifth of the wing. The upper branch gives off

* Sellards: Amer. Journ. Sci., vol. XVI, pp. 323–324, 1903; vol. XXII, pp. 249–258, 1906; vol. XXIII, pp. 345–355, 1907; vol. XXVII, pp. 151–173, 1909.

three or four veins; the lower branch is again divided before reaching the middle of the wing, each division being subdivided. Media divides opposite the termination of the anal area, each division giving off one or two simple branches. The cubitus is short and gives off three inferior branches, the second of which is forked. The anal area is of medium extent. Length of tegmina, partly estimated, 19 mm.; width 7 mm. Type in the American Museum of Natural History.

This species resembles in a general way *E. permiana* Sellards from the Permian of Kansas, an illustration of which is inserted for convenience of comparison (fig. 52 B). The radius of *E. texana*, however, divides much earlier and occupies a much larger area of the wing than does that of *E. permiana*. The cubitus of *E. texana*, on the other hand, is shorter and more lax than that of *E. permiana*.

Etoblattina (?) robusta sp. nov. (Text fig. 52 c.)

Large cockroaches. Tegmina broad in proportion to length. Subcostal area indistinctly preserved in the type specimen, but apparently broad. Radial area probably reaching to the tip of the wing. Media several times forked, its branches filling the inner part of the apex. Cubitus nearly straight and supplied with about six simple inferior branches. Anal area relatively long, traversed by eight or nine simple veins, the first four of which occupy more than half of the area. The imperfect preservation of the subcostal and radial areas renders the generic determination doubtful. Length of tegmina partly estimated, 30 mm.; width, 14 mm. Type specimen in the American Museum of Natural History.

THE PERMIAN FISHES OF NORTH AMERICA

By

LOUIS HUSSAKOF

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THE PERMIAN FISHES OF NORTH AMERICA.

INTRODUCTION.

The fishes of the Permian of North America were described by Cope in a series of papers published between 1875 and 1894. In a list of the vertebrata, which he compiled in 1890, 21 species of fishes are enumerated; to these he subsequently added an additional one, making a total of 22 species, representing 10 genera. They are divided among the major groups as follows:

	Genera.	Species.
Selachii	4	8
Dipneusti	4	11
Teleostomi	2	3
	10	22

From the data presented in the following pages it will be seen that several of Cope's species are not tenable. Some of his Permian material was too fragmentary for accurate diagnosis, and would better have been left unnamed. But, as was his custom, he gave names to most of this material in order to afford a handle by which to refer to it in discussions of the fauna. Moreover, Cope did not allow sufficient latitude to individual variation within the species, even slight differences being often regarded by him as specific. Hence it is not surprising that his list of species should have to undergo considerable change. A restudy of his types preserved in the American Museum of Natura History, of the material in the Gurley Collection at the University of Chicago, and also the study of some new material, result in the addition of four genera to Cope's list; but the number of species, on account of additions and subtractions, remains unchanged. These genera and species are divided among the various groups of fishes as follows:

	Genera.	Species.
Selachii	2	3
Ichthyotomi	2	4
Ichthyodorulites	2	2
Dipneusti	3	7
Crossopterygii	1	2
Actinopterygii	4	4
	14	22

SYSTEMATIC REVISION OF SPECIES.

SELACHII.

Genus JANASSA Münster.

Beitr. Petrefakt., 1832, p. 67.

Revised description of genus:

1. Depressed, ray-like sharks belonging to the extinct family *Petalodontidæ*.
2. Teeth in each jaw arranged in a pavement composed of several rows; those in median row the largest, and those in the lateral rows gradually diminishing in size.
3. Each tooth a flattened plate reflexed at both ends so as to appear ſ-shaped in lateral view; the proximal reflexed part the root. Middle portion of tooth traversed on inner surface by a series of fine ridges.

Carboniferous and Permian Periods. Represented in the Permian of America by two species, *Janassa strigilina* and *J. gurleyana*.

Janassa strigilina (Cope). (Plate 26, figs. 1–1*b*.)

1878. *Strigilina linguæformis* Cope, Proc. Amer. Philos. Soc., XVII, p. 52.
1881. *Janassa strigilina* (Cope), Amer. Nat., p. 163.
1887. *Janassa strigilina* (Cope), Trans. Amer. Philos. Soc., XVI, p. 285.
1889. *Janassa strigilina* (Cope), Woodward, Cat. Fos. Fishes, I, p. 38.
1900. *Janassa strigilina* (Cope), Case, Journ. Geol., VIII, p. 699, pl. I, figs. 1*a*–1*c*.

Type: A tooth, probably belonging to a median series. Gurley Collection, No. 6500 University of Chicago. Vermilion County, Illinois.

Original description of species: "The plicate surface terminates behind in a median angle, at the base of the root. There are eight plicæ which all cross the plane, excepting the sixth, which is interrupted in the middle by the strong angulation of the seventh, which touches the fifth. The lateral extremities of the right are in contact with the base of the recurved cutting portion. The latter is convex transversely, leaving a smooth surface between it and the eighth plica. The smooth side of the tooth is shining, and there is a shallow fold, which passes around its side and crosses just at the base of the recurved cutting lamina.

"*Measurements.*	M
"Total length of the plane	0.008
Width at base of the cutting lamina	.006
Width at the base of the root	.004
Thickness of plane portion	.0015"

Janassa gurleyana (Cope). (Plate 26, figs. 2–2*b*.)

1878. *Strigilina gurleiana* (Cope), Proc. Amer. Philos. Soc., XVII, p. 191.
1881. *Janassa gurleiana* (Cope), Amer. Nat., XV, p. 163.
1889. *Janassa gurleiana* (Cope), Woodward, Cat. Fos. Fishes, I, p. 39.
1900. *Janassa gurleyana* (Cope), Case, Journ. Geol., VIII, p. 700, pl. I, figs. 2*a*–2*c*.

Type: A small tooth lacking the root. Gurley Collection, No. 6501 University of Chicago. Vermilion County, Illinois.

This species is perhaps identical with *Janassa strigilina*, but based on a lateral tooth, whereas the former is based on a median one. In the absence of evidence on this point, however, it is best to retain the name *strigilina*, at least provisionally.

Original description: "The tooth is quite small, its length only equaling the width of the known tooth of *S.* [*Janassa*] *linguæformis*. It is also narrower in proportion to the length. The root and the cutting edge are turned in opposite directions, as in the other species. The principal difference between the two is seen in the character of the transverse ridges or crests of the oral face. There are two crests less, or five, with a delicate basal fold, making six, while, counting the fold, there are eight in *S.* [*Janassa*] *linguæformis*. The anterior ridge is transverse; the others slightly convex backwards, and all are equidistant and uninterrupted, which is not the case in the older species. They are also of different form, being distinct ridges with anterior and posterior faces similar. In *S.* [*Janassa*] *linguæformis* the anterior face only is vertical, the posterior descending very gradually, the whole forming a series of steps.

"Length of ridged face, 0.0060 m.; width anteriorly, 0.0035 m.; width posteriorly, 0.0020 m."

Janassa ordiana Cope (Am. Nat., xv, 1881, p. 163, and Trans. Am. Philos. Soc., xvi, 1888, p. 285) was mentioned by name only but never described. Its inclusion in the list was probably due to an oversight on Cope's part, and it should be dropped.

Thoracodus emydinus Cope (Proc. Academy Nat. Sci., Phila., 1883, p. 108) is, as suggested by A. S. Woodward (Catalogue Fossil Fishes British Mus., I, p. 39), an incomplete *Janassa* tooth; but it is too imperfectly defined to stand as a valid species.

(?) Genus HYBODUS Agassiz.

There are in the American Museum collections a number of fragments of a spine (No. 7263), too imperfect for description, which indicate, apparently, a species of *Hybodus* (plate 30, figs. 5, 5*a*). The fragments represent a large spine ornamented with smooth, coarse ridges closely apposed to one another and with a single series of small denticles running down the middle of the posterior face. Anterior margin of "cut water" without an enlarged rib.

ICHTHYOTOMI.

Genus PLEURACANTHUS Agassiz.

Poiss. Fos., III, 1837, p. 66.

The type genus of the Ichthyotomi—a group of extinct, primitive sharks ranging from the Upper Devonian to the Triassic, and reaching its maximum evolution in the Carboniferous.

Revised description of genus:

1. Skeleton cartilaginous, with minute prismatic calcifications.
2. Notochord persistent.
3. Neural and hæmal arches present.
4. Paired fins of the archipterygial type with segmented lateral branches.
5. Dorsal fin without spine, low, extending from a little back of the occiput to origin of caudal.

6. Caudal fin diphycercal.
7. Two anal fins.
8. A large denticulated spine attached to occipital region of cranium.
9. Teeth with two divergent cusps springing from a broad, flat base, and with one or more small median denticles.

Pleuracanthus quadriseriatus (Cope). (Plate 26, figs. 3–3*b*.)

1877. *Orthacanthus quadriseriatus* Cope, Proc. Amer. Philos. Soc., p. 192.
1889. *Pleuracanthus quadriseriatus* (Cope), Woodward, Cat. Fos. Fishes, I, p. 9.
1900. *Pleuracanthus* (*Orthacanthus*) *quadriseriatus* Cope, Case, Journ. Geol., VIII, p. 700, pl. I, figs. 3*a*–3*b*.
1902. *Pleuracanthus quadriseriatus* (Cope), Hay, Bull. U. S. Geol. Surv., No. 179, p. 264.

Type: Small fragment of a head spine, 7 mm. long, from near the distal end of the spine. No. 6502 Gurley Collection, University of Chicago; Vermilion County, Illinois (plate 26, figs. 3–3*b*).

Referred specimen: A small fragment of a head-spine associated with the type specimen (plate 26, fig. 3′).

The fragment upon which this species is based is from the distal portion of a spine—the part which shows less of the peculiarities of the spine than any other, since it is generally smoother and rounder than the proximal portion. But since the species has been described, the name must be retained, provisionally at least. Cope's diagnosis of it is as follows:

Original description: "The spine is wider than deep, and the series of denticles are widely separated. The surface between them is gently convex and smooth. The anterior face is strongly convex, and presents at each side two shallow furrows. The external groove is divided by a series of thin longitudinal denticles which are smaller than those of the principal row and which are sometimes confluent at the base. The principal denticles are closely placed, stout, acute, and recurved.

"Transverse diameter of shaft 0.0035 m.; anteroposterior diameter 0.0025 m.; the portion of the shaft preserved is straight."

Pleuracanthus gracilis (Newberry). (Plate 26, figs. 4–4*b*.)

1875. *Orthacanthus gracilis* Newberry, Paleont. Ohio, II, p. 56, pl. LIX, fig. 7.
1881. *Orthacanthus gracilis* Newb., Cope, Am. Nat., XV, p. 163.
1889. *Orthacanthus gracilis* Newb., A. S. Woodward, Cat. Fos. Fishes, I, p. 9.
1900. *Pleuracanthus* (*Orthacanthus*) *gracilis* Newb., Case, Journ. Geol., VIII, p. 701, pl. I, fig. 4.

This species is represented by a number of fragments of head-spines preserved in the University of Chicago collection (No. 6503), from the Red Beds in Vermilion County, Illinois. They may be distinguished at a glance from the preceding species by their circular cross-section and larger, more widely-spaced denticles. In the proximal portion of the spine the denticles of the two rows are placed opposite one another, while in the more distal portion they alternate, though not regularly. Newberry's definition of the species applies word for word to the fragments in hand and may here be appended:

Original description: "Spine small and straight, about three inches long, very slender and acute; section circular at base, posterior face and sides flattened above; the angle inclosed by them set with acute, recurved, com-

pressed denticles throughout the upper two-thirds of the entire length; surface smooth or very finely striated longitudinally."

Genus DIACRANODUS Garman. (Plates 28, 29, and part of 30.)

Bull. Mus. Compar. Zool., XII, 1885, p. 30.

The genus *Diacranodus* is at present known from crania and teeth only; it is therefore impossible to compare it in all details of its anatomy with *Pleuracanthus*. The crania of the two, however, seem to be sufficiently different to justify their separation generically. The characters of the cranium of *Diacranodus* are well brought out in the figures in plates 28 and 29, which are based on the types and one of the referred specimens of the type species, *D. texensis*. A restoration is also given, plate 29, figures 1, 1*a*.

Revised description of genus (based on skull):

1. Cranium fiddle-shaped; more shark-like than ray-like, as shown by the smallish rostral fontanelle.
2. Nasal capsules, auditory capsules, and postorbital processes well developed.
3. A pair of elongated bars (trabeculæ?), on the under side, in the median axis of the cranium, inclosing between them a small fossa (pituitary?).
4. Foramen magnum, on the under side of cranium, in the basisphenoid region.
5. Posterior face of cranium cup-shaped (for the articulation of the spine?).
6. Teeth as in *Pleuracanthus*.

Diacranodus texensis (Cope). (Plates 28, 29, and 30, figs. 9–9*b*.)

1883. *Didymodus* (?) *compressus* (Newb.) Cope, Proc. Acad. Nat. Sci. Phila., p. 108.
1884. *Didymodus compressus* (Newb.), Cope, Proc. Amer. Philos. Soc., XXI, p. 585, 1 pl.
1884. *Didymodus compressus* (Newb.), Cope, Amer. Nat., XVIII, pp. 413 and 818, pl. XXIII.
1885. *Pleuracanthus compressus* (Newb.), Cope, Proc. Amer. Philos. Soc., XXII, p. 406.
1885. *Diacranodus compressus* (Newb.), Garman, Bull. Mus. Compar. Zool., XII, p. 30.
1890. *Didymodus texensis* Cope, Trans. Amer. Philos. Soc., N. S., XVI, p. 285.
1900. *Pleuracanthus compressus* (Newb.), Case, Journ. Geol., VIII, p. 701.

Cotypes:

1. A complete, badly crushed cranium, figured by Cope in ventral view (erroneously interpreted as dorsal), 1884, *loc. cit.*, plate, fig. 1. No. 7928 Am. Mus.
2. The anterior portion of a cranium, figured by Cope, *loc. cit.*, plate, fig. 4. This memoir, pl. 28, figs. 1, 1*a*. No. 7929 Am. Mus.
3. The posterior half of a cranium, figured by Cope, *loc. cit.*, plate, figs. 2, 3 (ventral view, erroneously labeled as dorsal). This memoir, pl. 28, figs. 2, 2*a*. No. 7930 Am. Mus.
4. The facial portion of a cranium, showing upper and lower jaws from right side, and the hyomandibular, naturally articulated. Also two isolated teeth which probably do not belong with this head. Cope, *loc. cit.*, plate, figs. 5 and 6. This memoir, pl. 29, fig. 2. No. 7117 Am. Mus.

All from the Red Beds, Northwest Texas.

Referred material: Numerous well-preserved teeth; fragments of spines; several crania; the five teeth figured by Case, *loc. cit.*, No. 6504 University of Chicago.

Original description: "Skull with massive walls. Form elongate, depressed, the orbit not extending behind the anterior third of the length. Basicranial and basifacial axes in one line, flattened, the supraorbital border flat, concave on the edge; postorbital processes obtuse, the temporal ridges commencing with thin posterior border, which they excavate. The ridges then turn, extend parallel posteriorly, terminating in the horn-like processes already described, with a slight divergence. The apices mark the posterior third of the length of the skull. The occipital condyle is wider than deep, and its superior border retreats forwards so as to cause its cup to look upwards. The exoccipital diameter at the foramen magnum is less than that of the basicranial axis, the osseous element of which, probably sphenoid, is recurved on the sides to their middle. The sides of the latter expand a little to meet their lateral alæ. Immediately above their contact is situated the supposed condyle for the hyomandibular element. The basicranial axis is convex opposite the postorbital processes, from the bases of which a concavity separates it. It has a slight median groove at this point. It is much narrower than the interorbital width above. A short distance in front of the postorbital processes it begins to contract, and gradually reaches an acuminate apex. Superior to this apex, commencing posterior to it, the space between it and the supraorbital or nasal elements is occupied by a massive element (? ethmoid) which forms the floor of the nasal median fontanelle.

"The surfaces are smooth, but readily weather so as to be granular. The granules are subround, with flattened surface.

"*Measurements of skull.*	M
"Total length of skull to end of frontal bone (No. 1)	0.180
Total length of muzzle to orbit; axial	.024
Total length of skull to postorbital process	.058
Total length of skull to apices of frontal cartilage	.117
Total length of skull to (?) pterotic apex (axial)	.155
Width of skull at prefrontals	.045
Width of skull at supraorbital borders	.055
Width of skull at (?) pterotic apices	.088
Width of occipital condyle	.034
Depth of occipital condyle	.025

"*Measurements of jaws.*	M
"Length of mandibular ramus from cotylus, inclusive	0.145
Depth of mandibular ramus at cotylus	.028
Depth of mandibular ramus at middle	.035
Length of palatopterygoid bone from cotylus, inclusive	.145
Depth of palatopterygoid bone at postorbital articulation	.071
Depth of palatopterygoid bone at orbit	.035
Length of palatopterygoid bone posterior to orbit	.070"

Diacranodus platypternus (Cope). (Plate 30, fig. 8.)

1884. *Didymodus platypternus* Cope, Amer. Nat., XVIII, p. 818, pl. XXIII, figs. 8, 9.
1884. *Didymodus platypternus* Cope, Proc. Amer. Philos. Soc., XXI, p. 587, plate, figs. 8, 9.
1885. *Diacranodus platypternus* (Cope), Garman, Bull. Mus. Compar. Zool., p. 30.
1890. *Didymodus platypternus* Cope, Trans. Amer. Philos. Soc., N. S., XVI, p. 285.

Type: Numerous fragments of a pair of large jaws and two imperfect teeth. No. 7243 Am. Mus. Texas.

This species is not well differentiated from the preceding, owing to the paucity of material. No sufficient reason for separating it can be found in the peculiarities said by Cope to be present in the teeth—as has already been pointed out by Broili (7). The material available indicates a form of larger size than *Diacranodus texensis*. Its distinctive characters as given by Cope are the following:

Original description: "The lower jaw is distinguished from that of the *D. compressus* by its small transverse as compared with its other diameters. The ramus is quite compressed, and is not thicker at the inferior edge than the superior, and is slightly concave on the inner side. Its external face is nearly vertical. The angle is rounded forwards, and there is no angle behind the cotylus, which is raised above the superior line of the ramus. The cotylus is rather large, and has a shallow anterior superior, and a posterior subposterior facet. There is no indication of a coronoid process. The inferior edge of the ramus is swollen on the outer side, below the anterior border of the condyle, so as to mark with the thickened posterior edge of the ramus a fossa in the position of the masseteric."

ICHTHYODORULITES.

Genus CTENACANTHUS Agassiz.

Poiss. Fos., III, 1837, p. 10.

A provisional genus of sharks, to which are referred numerous paleozoic dorsal fin-spines, known to have had (at least in certain species referred to the genus) cladodont dentition and primitive fin-fold paired fins.

Revised description of genus:

1. Dorsal spines straight or gently arcuate, and more or less laterally compressed.
2. Lateral faces longitudinally ridged, the ridges smooth or ornamented with various types of denticulations or beading.
3. Posterior face flat or concave, usually with a series of small denticles along each margin.

Ctenacanthus amblyxiphias Cope. (Plate 30, figs. 6–6*a*.)

1891. *Ctenacanthus amblyxiphias* Cope, Proc. U. S. Nat. Mus., XIV, p. 449, pl. xxviii, fig. 3.

1902. *Ctenacanthus amblyxiphias* Cope, Hay, Bull. U. S. Geol. Surv., No. 179, p. 327.

Type: An imperfect spine. When complete about 25 or 30 cm. No. 7283 Am. Mus. Texas. *Referred specimen:* No. 7282 (plate 30, fig. 6).

Original description: "Spine elongate, but little curved, moderately compressed; the posterior face with a flat median plane bounded by a shallow groove on each side. The ridges are wider than their interspaces, and they gradually become smaller posteriorly, so as to be half the diameter of the anterior ribs. The anterior border consists of a single rib of twice the diameter of the largest lateral ribs. Its front surface is smooth; the sides are marked with shallow grooves directed downward, and the border is serrate with subacute tubercles, which point backward. The tubercles of the ribs are closely placed and vary from round to transverse in shape, and have a finely grooved surface. The line of the posterior hooks is flush with the sides of the spine. They are small, decurved, and subacute."

Genus ANODONTACANTHUS J. W. Davis.

Quart. Journ. Geol. Soc., XXXVII, 1881, p. 427.

A genus of ichthyodorulites represented in the Coal Measures of England and in the Permian of Bohemia and Texas. It may be defined as follows:

Revised description of genus:

1. Spines straight, or very gently arched, as viewed from the side.
2. No denticles along posterior margin.
3. Lateral faces ornamented either with incised lines which are discrete for some distance and then anastomose or end abruptly; or with lines and pittings arranged so as to give a reticulated appearance.
4. Pulp-cavity circular in cross-section, completely inclosed, large (occupying about one-third the width of the cross-section in the proximal part of the spine) and gradually diminishing in diameter distalward.

In 1881, J. W. Davis described (**50** *a*) three species of Carboniferous fish-spines, two from Yorkshire and one from near Edinburgh, for which he proposed the generic name *Anodontacanthus.* They differed from all other ichthyodorulites in the absence of denticles along the posterior margin; but in several respects they were suggestive of the head-spines of *Pleuracanthus*, enough so, in fact, to raise the question whether *Anodontacanthus* might not really be identical with this genus.

In 1888, Traquair showed that one of these three species—the one from Scotland, *Anodontacanthus fastigiatus*—was a weathered Pleuracanth spine. In a large series of these spines he found that some "are smooth and without denticles, others show, in all stages of apparent wearing away, undoubted stumps of denticles, whereby the species *fastigiatus* falls into *Pleuracanthus*" (**66** *a*). The removal of one of the three species of *Anodontacanthus* to *Pleuracanthus* did not, of course, invalidate *Anodontacanthus*, which should still be retained as a provisional genus.

In 1889, Fritsch in his "Fauna der Gaskohle," page 113, plate 86, fig. 5, described and figured a similar spine from the Permian of Bohemia, to which he gave the name *Platyacanthus ventricosus.* This spine falls within the definition of *Anodontacanthus* and hence *Platyacanthus* must be regarded as a synonym.

The genus is represented in the Permian of Texas by a distinct species which is described below.

Anodontacanthus americanus n. sp. (Plate 26, figs. 5–5*b*.)

Type: A spine lacking both distal and proximal extremities. Length of preserved portion, 59 mm. Diameter at widest part, 10 mm. No. 7934 Amer. Mus. Red Beds, Texas.

This species is distinguishable from the Bohemian one, *A. ventricosus* (Fritsch), by its smaller size, the shape of its cross-section and the absence of pittings in the striations. The American form is stouter and not such an elongated ellipse in cross-section (the character which had apparently suggested the generic name *Platyacanthus* to Fritsch). From the two Carboniferous species it is distinguished by its cross-section and by the details of ornamentation.

DIPNEUSTI.

Genus SAGENODUS Owen.

Trans. Odontol. Soc., v, 1867, p. 365.

Description of genus:

1. Body-form resembling that of the living *Neoceratodus*.
2. Head covered with numerous plates, of which one is a large median occipital; a smaller median plate in front of it.
3. Scales large, thin, irregularly ovate, or polygonal with rounded angles.
4. Scales and external bones without a layer of ganoine.
5. Dental plates, triangular, irregularly ovate, with few radiating ridges, which may be smooth, or more or less crenulated or denticulated.
6. Caudal, continuous with dorsal and anal fins.

Sagenodus dialophus (Cope). (Plate 26, figs. 6, 7.)

1878. *Ctenodus dialophus* Cope, Proc. Amer. Philos. Soc., XVII, p. 528.
1881. *Ctenodus dialophus* Cope, Amer. Nat., XV, p. 162.
1888. *Ctenodus dialophus* Cope, Trans. Amer. Philos. Soc., XVI, p. 285.
1891. *Sagenodus dialophus* (Cope), Woodward, Cat. Fos. Fishes, Brit. Mus., II, p. 261.
1899. *Sagenodus dialophus* (Cope), Williston, Kans. Univ. Quart., Ser. A. VIII, p. 176.

Type: Left lower dental plate lacking portions of first two ridges. No. 7234 Am. Mus. Cope Collection. Texas.

Referred specimen: An imperfect dental plate; Texas. No. 7470 Am. Mus.

Original description: Dental plate "of narrow form, and has more numerous crests than any other known American species. They number ten, and there are two or three other rudimental ones at the posterior extremity. They are all more transverse than usual, five being directed forwards and five slightly backwards. The crests are acute, but the grooves and emarginations are not very deep. The crests are entire, except at the obliquely truncate distal extremities, where there are from two to four dentations. The shining layer does not extend within these. The inner border of the tooth is vertical, excepting posteriorly, where the inner border of the crest-bearing portion turns outwards, leaving a narrow ledge of the palatal face. The latter is concave in cross-section.

"*Measurements.*	M
"Length (0.004 at one end inferential)	0.033
Width at fifth crest	.010
Depth opposite fifth crest	.004"

Sagenodus fossatus (Cope). (Plate 26, figs. 8–11.)

1877. *Ctenodus fossatus* Cope, Proc. Amer. Philos. Soc., XVII, p. 53.
1877. *Ctenodus gurleyanus* Cope, Proc. Amer. Philos. Soc., XVII, p. 54.
1878. *Ctenodus porrectus* Cope, Proc. Amer. Philos. Soc., XVII, p. 527.
1883. *Ctenodus vabasensis* Cope, Proc. Acad. Nat. Sci. Phila., p. 110.

Type: An imperfect, immature, left mandibular plate. No. 6506 University of Chicago Gurley Collection. Vermilion County, Illinois.

Referred specimens:

1. The type of *Ctenodus gurleyanus* Cope—an upper dental plate. Vermilion County, Illinois. No. 6509 University of Chicago.
2. Type of *Ctenodus porrectus* Cope—a lower (?) dental plate. Vermilion County, Illinois. No. 7235 American Museum.
3. Type of *Ctenodus vabasensis* Cope—one dental plate. Vermilion County, Illinois. No. 6510 University of Chicago.

This species was founded on an immature, imperfect dental plate. Subsequently well-preserved, mature plates were obtained by Cope from the same locality and described as distinct species under the names given in the synonymy above. It appears very plainly, however, after a comparison of ten dental plates in the American Museum and in the University of Chicago collections, representing these forms, that they are only variations of one species. For this the name *Sagenodus fossatus* should be used because of priority.

Revised description: Dental plate with six or seven ridges radiating from an inner smooth area; these ridges separated from one another by very deep grooves. Each ridge with several (three to six) coarse denticulations in its distal half, but proximal half sharp and even, gradually descending towards the inner smooth area.

Sagenodus (*Ctenodus*) *heterolophus* Cope (Proc. Acad. Nat. Sci. Phila., 1883, p. 109) was founded on "a single broken tooth" which was described but not figured. The description is quite inadequate, leaving open the question whether the specimen was not an imperfect *S. fossatus*. The whereabouts of the type are unknown. A specimen in the American Museum, No. 7473 (plate 27, fig. 6), is perhaps this type, as it answers in a measure to the dimensions given by Cope; but of this there is no certainty. It presents the three anterior ridges of a lower dental plate, of which the most anterior ridge is higher than the succeeding ones. On the whole, *S. heterolophus* can not be regarded as a valid species since it was not sufficiently described.

Sagenodus paucicristatus (Cope). (Plate 27, figs. 4, 4*a*.)

1877. *Ceratodus paucicristatus* Cope, Proc. Amer. Philos. Soc., XVII, p. 53.
1877. *Ptyonodus paucicristatus* Cope, *Ibid.*, p. 192.
1891. *Sagenodus paucicristatus* Cope, Woodward, Cat. Fos. Fishes, Brit. Mus., II, p. 261.
1899. *Sagenodus paucicristatus* Cope, Williston, Kans. Univ. Quart., Ser. A, VIII, p. 175.
1900. *Sagenodus paucicristatus* Cope, Case, Journ. Geol., VIII, p. 707.

Type: An imperfect dental plate. No. 6505 University of Chicago Gurley Collection. Vermilion County, Illinois.

Original description: "The single tooth representing this species is narrow in the transverse direction, but stout in vertical diameter. But four ridges are present, all of which have a single direction, but the shorter ones are the less oblique to the long axis of the tooth. They all extend into the inner border, but become low as they approach it. Distally they are quite prominent, but do not project very far beyond the emarginate border between them. The inner border is plane and vertical, and without ledge; the inferior surface is concave in the transverse direction. The surface of the tooth is minutely and elegantly corrugated.

"*Measurements.*

	M
"Length from base to second rib	0.0170
Depth at base of second rib	.0045"

I may add that while only four ridges are preserved in the type, a comparison with other species indicates that at least two more must have been present. The ridges are sharp and devoid of the denticulations so conspicuous n some other species, *e.g.*, *Sagenodus fossatus;* the second ridge, however, shows at its distal end two faint elongated crenulations.

Sagenodus periprion (Cope). (Plate 27, figs. 5–5*a*.)

1878. *Ctenodus periprion* Cope, Proc. Amer. Philos. Soc., XVII, p. 527.
1881. *Ctenodus periprion* Cope, Amer. Naturalist, XV, p. 162.
1888. *Ctenodus periprion* Cope, Trans. Amer. Philos. Soc., XVI, p. 285.
1891. *Sagenodus periprion* (Cope), Woodward, Cat. Fos. Fishes, Brit. Mus., II, p. 261.
1899. *Sagenodus periprion* (Cope), Williston, Kans. Univer. Quart., Ser. A, VIII, p. 176.

Type: A left palatal plate, defective at anterior and posterior extremities. No. 7474 Am. Mus. Cope Collection. Texas.

Original description: "This large species is indicated by a fine palatal tooth of the left side. Its outline approaches that of a right-angled triangle, but the hypothenuse is deeply incised by the interradial notches. The plate is rather thin, and is moderately concave on the inferior face. The ridges number seven, all of which are directed outwards and forwards. They are separated by strong grooves, have a perfectly smooth and uniform crest, and become more elevated at the distal extremities. The latter are steeply decurved and serrate, both faces being invested with a polished enamel-like layer. This substance is only visible in an edge view, and covers one-half the depth of the margin, being excavated by the extremities of the radiating grooves. The superior face is flat.

"The absence of serration from the radiating ridges of this species is a striking feature, allying it to the genus *Ptyonodus*, where the teeth are wanting.

"*Measurements.*	M
"Length of dental plate	0.037
Width of dental plate	.018
Thickness at inner border	.005
Thickness at external border of penultimate crest	.007"

Sagenodus vinslovi (Cope). (Plate 27, figs. 7–8.)

1875. *Ceratodus vinslovi* Cope, Proc. Acad. Nat. Sci. Phila., p. 410.
1877. *Ceratodus vinslovi* Cope, Proc. Amer. Philos. Soc., XVII.
1877. *Ptyonodus vinslovi* (Cope), *Ibid.*, p. 192.
1891. *Sagenodus vinslovi* (Cope), Woodward, Cat. Fos. Fishes, Brit. Mus., II, p. 262.
1899. *Sagenodus vinslovi* (Cope), Williston, Kans. Univer. Quart., Ser. A, VIII, p. 176.
1900. *Sagenodus vinslovi* (Cope), Case, Journ. Geol., VIII, p. 703, pl. I, figs. 6*a*–6*b*.

Type: A left palatal plate defective at anterior extremity. No. 6507 University of Chicago Gurley Collection. Vermilion County, Illinois.

Referred specimen: A left palatal from Texas, also defective anteriorly. No. 7233 Am. Mus. Cope Collection.

Revised description: Dental plate relatively thin; coronal face traversed by six ridges radiating from an inner smooth area, which occupies one-third to one-half the width of the entire element; ridges smooth, without serrations, rising gradually towards their distal extremities, which are cusp-like. Depressions between ridges wide and shallow.

Genus CERATODUS Agassiz.

Poiss. Fos., III, 1838, p. 129.

Revised description of genus:

1. Body-form similar to that of the living *Neoceratodus*.
2. Head with relatively few, thin bones; two ("ethmoid" and "occipital") in the median line, one behind the other; three pairs of lateral plates symmetrically disposed on either side of these.
3. Scales large and thin.
4. Paired fins, archipterygia with biserial radials, and covered with scales.
5. Dental elements irregularly triangular, with ridges developed into stout cusps, without lateral denticles.

Ceratodus favosus Cope. (Plate 27, figs. 11, 11*a*.)

1884. *Ceratodus favosus* Cope, Proc. Amer. Philos. Soc., XXII, p. 28.
1888. *Ceratodus favosus* Cope, Trans. Amer. Philos. Soc., XVI, p. 286.
1891. *Ceratodus favosus* Cope, Woodward, Cat. Fos. Fishes, Brit. Mus., II, p. 274.
1908. *Ceratodus favosus* Cope, Hussakof, Bull. Amer. Mus. Nat. Hist., XXV, p. 51.

Type: A fragment of a splenial with portion of a dental element showing two cusps. No. 7230 Am. Mus. Cope Collection. Texas.

In the writer's opinion the type of this species was too fragmentary for specific description. Its distinctive characters are given by Cope as follows:

Original description: "The species may be distinguished from those described by Agassiz, and from the existing species, by the great depth of the two emarginations of the external side. These enter the crown so deeply as to reduce its width to dimensions no greater than those of each of the processes of the crown. The internal face is strongly convex, and one extremity is more strongly recurved than the other."

The first of these two supposedly distinctive characters applies equally well to some dental elements of *Neoceratodus forsteri*. In fact I have a dentition of this species before me in which the emarginations are certainly as deep as in the type of *C. favosus*. And as to the second character, namely, that "the internal face is strongly convex, and one extremity is more strongly recurved than the other"—that I believe will apply equally well to many other ceratodont dental plates. The convexity of the internal face in these dental elements is quite variable. All that should have been concluded from the specimen was the presence of *Ceratodus* in the Permian of America; but no new species should have been founded upon it. However, since the species has been established, we have no alternative but to retain it until better material comes to light and proves it either valid or merely a synonym.

Genus GNATHORHIZA Cope.

Proc. Amer. Philos. Soc., XX, 1883, p. 629.

The genus *Gnathorhiza* was founded by Cope on small dental elements which he thought "very doubtfully * * * may belong to the Petalodont family." Since the date of his description, however, several similar elements have been discovered, and from these it is quite certain that they represent the dental system of a dipnoan and not of a shark. This dipnoan, as far as one may infer from the dental plates alone, differed strongly from all others and should stand as generically distinct.

Cope's description of *Gnathorhiza* was given in a single paragraph, which was unaccompanied by figures, and otherwise left doubts open concerning the diagnostic characters of this form; for one reason, because of his comparison of these dental elements with sharks' teeth. It would have been difficult to recognize his genus again merely by his description had it not been for the preservation of his type specimen in the American Museum of Natural History. Before any figures of it were published, however, Dr. Eastman described two similar dental elements under the name *Sagenodus pertenuis* (**50** *b*). He recognized the anomalous character of this dipnoan, and gave an accurate description of its dental elements accompanied by excellent figures. His view of the peculiarities of this type of dipnoan dentition is given in these words:

[This fish] "occupies a unique position amongst fossil dipnoans in having a dentition adapted for cutting instead of crushing, thus paralleling the conditions found in certain Palæozoic sharks and in recent Gymnodonts. This divergence is the more striking in view of the singularly uniform type of dental system pervading lung-fishes throughout their entire geological history."

In 1908 the writer figured the type specimen of *Gnathorhiza* for the first time and called attention to its identity with the form described as *Sagenodus pertenuis* by Eastman (**55** *a*).

Of the dental elements referable to *Gnathorhiza*, three distinct species have been made:

1. *Ctenodus pusillus* Cope, 1877, based on a very small dental plate from Illinois.
2. *Gnathorhiza serrata* Cope, 1883, based on a small dental plate from Texas.
3. *Sagenodus pertenuis* Eastman, 1903, based on two small dental plates from Illinois (?).

A study of the types of these species, however, shows that they are all of the same genus (*Gnathorhiza*), and probably of one species. For this species the name *pusilla* should be retained because of priority. A difference is observable between the *pusilla* and the *serrata* forms—the former having *two* and the latter but *one* transverse coronal ridges. This, however, is not sufficient reason for separating them specifically, since variations in the number of ridges in dipnoan dental elements is quite common. Furthermore, as remarked by Dr. Eastman, it is probable that the superior dental plate of this form had one ridge more than the lower.

The generic characters of *Gnathorhiza* are comprised in the description of *G. pusilla*, the only known species, below:

Gnathorhiza pusilla (Cope). (Plate 27, figs 9–10.)

1877. *Ctenodus pusillus* Cope, Proc. Amer. Philos. Soc., XVII, p. 191.
1883. *Gnathorhiza serrata* Cope, Proc. Amer. Philos. Soc., XX, p. 629.
1888. *Gnathorhiza serrata* Cope, Trans. Amer. Philos. Soc., XVI, p. 286.
1891. *Sagenodus pusillus* (Cope), Woodward, Cat. Fos. Fishes, Brit. Mus., II, p. 261.
1899. *Sagenodus pusillus* (Cope), Williston, Kans. Univer. Quart., Ser. A, VIII, p. 176.
1900. *Sagenodus pusillus* (Cope), Case, Journ. Geol., VIII, p. 705, pl. I, figs. 9*a*, 9*b*.
1903. *Sagenodus pertenuis* Eastman, Amer. Nat., XXXVII, p. 493, figs. 1-2.
1908. *Gnathorhiza serrata* Cope, Hussakof, Bull. Amer. Mus. Nat. Hist., XXV, p. 53, fig. 25.

Type: A small right palatal plate. No. 6508 University of Chicago Gurley Collection. Vermilion County, Illinois.

Referred specimens:

1. A right mandibular element, the type of *Gnathorhiza serrata*. No. 7258 Am. Mus. Cope Collection. Texas.
2. A left mandibular collected by Case in Texas, larger and better preserved than either of the preceding. No. 7935 Am. Mus.

Description of species: Dental plates relatively small, with oral face adapted for cutting or chopping rather than grinding. Inner oral margin compressed into a sharp edge angulated near its middle and with one or two sharp ridges radiating from the angulation; anterior moiety of coronal ridge with two or three broad denticulations; posterior moiety, as well as radiating ridges, finely serrated.

CROSSOPTERYGII.

Genus MEGALICHTHYS Agassiz.

Poiss. Fos., II, pt. 11, 1844, pp. 89, 154.

A Crossopterygian genus belonging to the family *Osteolepidæ*.

Revised description of genus:

1. Cranial bones arranged as in typical *Osteolepidæ*, with paired frontals and parietals.
2. Throat region protected by a pair of large gular plates, an anterior median gular plate, and a series of small lateral plates.
3. Teeth conical, those in front part of jaw much larger than the others.
4. Vertebræ ossified in the form of rings, with well-developed neural and hæmal arches.
5. Paired fins covered with scales except in their distal portions.
6. Dorsal fins two in number: the first opposed to the ventrals; the second a short distance in advance of the anal.
7. Caudal fin, heterocercal.
8. Scales thick, covered with ganoine and finely punctate.

Carboniferous and Permian.

The Permian species of *Megalichthys* were originally described by Cope as a new genus, *Ectosteorhachis*. The distinction between this genus and *Megalichthys*, according to him, consists in differences in the form of the vertebral centra. "Both Agassiz and Huxley describe those of *Megalichthys* as completely ossified and as biconcave. In *Ectosteorhachis* they are represented by annular ossifications resembling somewhat those of the stegocephalous genus *Cricotus*, but with a larger foramen *Chordæ dorsalis*" (**25**, p. 56).

Regarding this distinction it may be said that the vertebræ of Cope's *Ectosteorhachis* do not differ markedly from those of *Megalichthys* as figured, for instance, by Wellburn.* In both they are narrow rings, but those in Cope's specimen (see plate 30, figs. 1, 2) are not well enough preserved to make it absolutely certain that they were complete, and not open, above.

In all other respects, so far as the state of preservation of Cope's specimen allows of comparison, *Ectosteorhachis* and *Megalichthys* are the same. Hence the latter name should be employed for *Ectosteorhachis*.†

* Proc. Yorkshire Geol. and Polytechnic Soc., 1900, pl. xix, fig. F.

† Dr. O. P. Hay has pointed out (**54**, p. 362) that the name *Megalichthys* was first applied to the fishes generally known as *Rhizodus*. And hence *Rhizodus* should, properly, be called *Megalichthys*, because of priority; and the genus generally called *Megalichthys* should have its name changed to *Parabatrachus* Owen, which is an available synonym. But in view of the confusion which would result in thus reversing a usage which has been in vogue for eight decades and has become thoroughly established in the science, the writer deems it best to retain the name *Megalichthys* in its present general usage.

Megalichthys nitidus (Cope). (Plate 30, figs. 1–4; plate 31, figs. 3–3*b*.)

1880. *Ectosteorhachis nitidus* Cope, Proc. Amer. Philos. Soc., XIX, p. 56.
1888. *Ectosteorhachis nitidus* Cope, Trans. Amer. Philos. Soc., XVI, p. 286.
1891. *Megalichthys nitidus* (Cope), Proc. U. S. Nat. Mus., XIV, p. 457, pl. XXXII, figs. 8, 9.
1891. *Megalichthys nitidus* (Cope), Woodward, Cat. Fos. Fishes, Brit. Mus., II, p. 388.
1899. *Parabatrachus nitidus* (Cope), Hay, Amer. Nat., XXXIII, p. 788.

Type: Head and trunk, including ventral fins, of a large fish. No. 7239 Am. Mus. Texas.

Referred specimen: Cranium and some vertebræ. No. 7936 Am. Mus. Archer County, Texas.

The principal points in the specific diagnosis may be condensed from Cope's original description as follows:

Original description: "Pectoral fins originate further behind the head than is usual. The ventrals are well posterior and close together. * * * The orbits are in front of a transverse line dividing the skull equally. The muzzle is broadly rounded, and is covered with rounded plates of ganoine. Several of these have median perforations. * * * The top of the head behind the muzzle is entirely without ganoine layer in two specimens; its surface is smooth, or weakly finely ridged. On the other hand the premaxillary, maxillary, mandibular, and gular bones are invested with perfectly smooth ganoine.

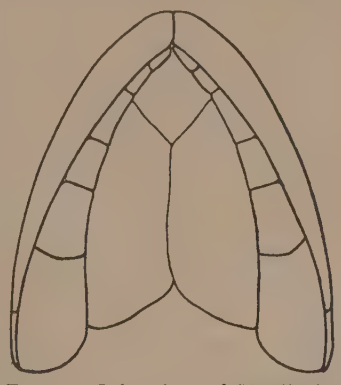

FIG. 53.—Gular plates of *Megalichthys nitidus* (Cope); diagrammatic.

"The pectoral fins are quite wide, and their rays diverge exclusively from the inner border, and are very fine. The axial portion is thick and acuminate, and has no fulcra on the external edge, but is covered with quadrate and rhomboidal scales, of very much smaller size than those of the body. The axial portion of the ventral fins is not quite so large as that of the pectoral.

"The scales of the body are quite large and overlap each other by both the free edges. Though their form is rhombic, the apex is rounded. The surface is ganoid, and entirely smooth. There are five rows between the internal bases of the ventral fins, and twelve between the external bases of the pectorals."

Megalichthys ciceronius (Cope).

1883. *Ectosteorhachis ciceronius* Cope, Proc. Amer. Philos. Soc., XX, p. 628.
1888. *Ectosteorhachis ciceronius* Cope, Trans. Amer. Philos. Soc., XVI, p. 286.
1891. *Megalichthys ciceronius* (Cope), Woodward, Cat. Fos. Fishes, Brit. Mus., II, p. 388.
1891. *Megalichthys ciceronius* (Cope), Proc. U. S. Nat. Mus., XIV, p. 457.
1899. *Parabatrachus ciceronius* (Cope), Hay Amer. Nat., XXXIII, p. 788.
1900. *Megalichthys ciceronius* (Cope), Wellburn, Proc. Yorkshire Geol. and Polytechnic Soc., p. 60.

This species was founded on two imperfect crania, which have thus far not been identified among the material in the Cope collection in the American Museum; nor have they been found in any other collection. Cope's diagnosis of the species was as follows:

Original description: "The *E. ciceronius* differs from the *E. nitidus* in having a narrower interorbital region, and in the possession of small

tubercles of ganoine on the posterior parts of the superior surface of the skull. These are seen on the sides of the surface, and are quite small, not numerous, and of various sizes and shapes. They resemble shining seeds. In *E. nitidus* these points are wanting, but there are rugosities on the postfrontal and pterotic regions of a radiating character, not found in *E. ciceronius*.

"*Measurements.*

		M
"No. 1.	Length of skull to occiput above (muzzle worn)	0.069
	Interorbital width	.014
No. 2.	Length of osseous base of cranium (parachordal)	.039
	Length of open median groove	.022
	Width of base at parachordals	.036
	Width of groove at apices of parachordals	.011
	Width of foramen notochordæ	.0095"

ACTINOPTERI.

Genus SPHÆROLEPIS Fritsch.

Sitzungsb. k. böhm. Gesell. Wiss., 1877, p. 46.

In 1877 (22) Cope described a small dentigerous plate which he considered, with evident doubt, "a pharyngeal, pterygoid, palatine or half of the vomerine element" of a Crossopterygian, and referred it to his genus *Peplorhina* as a new species, *P. arctata*.

In 1882 (31) he abandoned this interpretation and declared the element to belong to a theromorphous Saurian.

In 1900 (11) Case examined this element and wrote concerning it that while it "certainly has much the appearance of the small teeth which occur in the roof of the mouth in certain of the Cotylosauria and may very possibly belong there"—still a second specimen of this dentigerous plate (University of Chicago, 6512) which was quite perfect, and with which the first entirely agreed, was of undoubted Crossopterygian origin and hence Cope's original interpretation was correct and his name *Peplorhina arctata* should be retained.

A third dentigerous element of the same kind was obtained by Prof. Case on a recent collecting trip to Texas. This element (fig. 54 A) is a fragment of a larger plate which was covered with denticles quite like those of Cope's type specimen; and it apparently represents the same genus. Prof. Case also collected a small fragment with conical teeth (fig. 54 B), of either the mandible or the maxillary, which probably also belongs to the same form.

In regard to their relationship: it seems to the writer that these elements agree quite well with the type of teeth figured by Professor Fritsch in his genus *Trissolepis* (Fauna der Gaskohle, III, pl. 109, fig. 1; pl. 110, figs. 1 and 2)—a form he had previously named *Sphærolepis* and which name should be retained, because of priority.

In view of this identification of the elements from the Permian of Texas with *Sphærolepis* of the Permian of Bohemia, the names *Sphærolepis* Fritsch and *Peplorhina* Cope become synonymous; *Peplorhina* has priority, but for the following reasons it should not be retained, being an insufficiently defined genus.

Peplorhina was established by Cope in 1873 on fragmentary material from the Coal Measures of Ohio with *P. anthracina* as the type species.*

* Proc. Acad. Nat. Sci., Phila., 1873, p. 343.

It was at once pointed out by Newberry that the material representing this genus was "too imperfect for satisfactory study" and that it represented an amphibian and not a fish.*

In 1875 Cope emended his description, published a figure of the type, and gave his grounds for regarding the species as fish and not amphibian.†

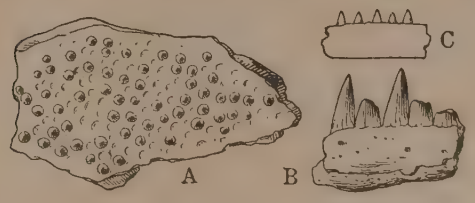

FIG. 54.—*Sphærolepis arctata* (Cope). × 2.
A. Fragment of a palatal (?) plate, bearing denticles. No. 7932 Am. Mus.
B. Fragment of mandible or maxilla, bearing relatively large conical, partly striated teeth.
C. Specimen shown in A, in side view.

But it is evident, on even little study, that neither his figure nor his diagnosis offers any distinctive characters by which one could recognize this genus in a lot of material. Some of the characters he enumerated were undoubtedly derived from a specimen of *Cœlacanthus* which, as appears from his figures, had become mixed up with his type specimen.‡

For these reasons *Peplorhina* is to be looked upon as an insufficiently defined genus, and *Sphærolepis* Fritsch should be substituted.

Sphærolepis arctata (Cope). (Plate 31, figs. 1–2*a*, text fig. 54.)

1877. *Peplorhina arctata* Cope, Proc. Amer. Philos. Soc., p. 54.
1882. *Theromorphus saurian* Cope, Proc. Amer. Philos. Soc., p. 461, footnote.
1891. *Peplorhina arctata* Cope, Woodward, Cat. Fos. Fishes, II, p. 408.
1900. *Peplorhina arctata* Cope, Case, Journ. Geol., VIII, p. 707.

Type: A fragmentary dentigerous plate. No. 6511 University of Chicago. Vermilion County, Illinois.

Referred specimens:

1. A small symmetrical element bearing similar teeth and from the same locality as the type. No. 6512 University of Chicago.
2. A fragment of a larger palatal (?) plate than either of the two preceding specimens, bearing similar teeth. Texas. Collected by Dr. E. C. Case. No. 7932 American Museum.
3. A small fragment of a mandible or maxilla bearing relatively large conical teeth, which are striated in their lower half.

Original description of species: "The bone is plate-like and diamond-shaped, with the longer angles both recurved. The convex surface is thickly studded with teeth which are not in contact with each other. Their size increases from one side of the bone to the other, and still more, from one extremity to the other. The crowns are swollen at the nearly sessile base, and contract rapidly to a conical and unsymmetrical apex. Those of the smaller teeth are more conical, those of the larger more bulbiform. One side of the latter is slightly concave below the apex. The surface is shiny and distinctly grooved. Fractured crowns do not display any central cavity. There are sixty-five teeth on the plate.

* Proc. Acad. Nat. Sci., Phila., 1873, p. 426.
† Geol. Sur. of Ohio, II, pt. ii, Palæont., p. 409.
‡ *Ibid.*, pl. xlii, fig. 4.

"*Measurements.*	M
"Length of plate	0.013
Width on short border	.007
Transverse width	.007
Depth	.002"

Genus SPERMATODUS Cope.

Journ. Acad. Nat. Sci. Phila., 2d ser., IX, 1894, p. 438.

An imperfectly known genus founded on half of a much-crushed skull. It was regarded by Cope as a Crossopterygian and the type specimen was thought to resemble closely the skull of *Polypterus*. To the writer, however, the resemblance to *Polypterus* is not so apparent; and it is even doubtful whether it is a Crossopterygian. Provisionally the genus may be placed in the Actinopteri. Its peculiarities—as far as they may be inferred from only a very poorly preserved half of a skull—are given below:

Revised description of genus:

1. Basioccipital of skull with a cotyloid cavity for the first vertebra and situated in front of the foramen magnum.
2. Parasphenoid covered from its posterior third to near the anterior extremity with small, delicate teeth.
3. Surface of skull ornamented with minute tubercles of enamel.

Additional characters are given under the specific description below.

Spermatodus pustulosus Cope. (Plate 32.)

1894. *Spermatodus pustulosus* Cope, Journ. Acad. Nat. Sci. Phila., 2d ser., IX, p. 438, text fig. 4.

Type: Left half of a badly crushed skull. No. 7245 American Museum. Texas.

Original description: "The general shape of the head is broad and flat. The occipital cotylus is circular in outline. The parasphenoid tooth-patch has an elliptic posterior outline, and the teeth are crowded, and measure from 0.4 to 0.3 millimeter in diameter. The parasphenoid is 5.5 times as long as wide at the middle. There are two rows of palatine teeth, but whether they are on different bones or on a single crushed bone is not easy to determine. They are displayed on the superior surface of the specimen by the crushing of the parts. The teeth are rapiform, with acuminate apex and striate enamel. They generally stand four in a space of five millimeters, with short interspaces. The largest are a millimeter in diameter. In the longest row, probably imperfect, there are eight teeth. The cranial sculpture is probably considerably worn off by exposure. It remains on parts of the frontal and maxillary bones. It resembles greatly a collection of minute pustules. The bony tissue is elevated into small tubercles, which are capped with enamel, which is abruptly distinguished from the osteine. When the enamel is lost there remains a pit in the tubercle. The tubercles are oval on the frontal, and oat-shaped at one point on the maxillary.

"The basihyal is turned with the anterior face posteriorly. This face is not divided into two for the hypohyals as in *Polypterus bichir*. It is a transverse oval with one long side flat, and the other concave. The ceratohyal is flat, and becomes quite thin posteriorly. Its anterior extremity is excavated into an oval cup. The supposed mandible is flat, and in a horizontal plane, but is more robust than the ceratohyal. If there were any orbital bones they have left no traces.

"*Measurements.*	MM
"Transverse diameter skull near posterior end of maxillary	200
Length of parasphenoid	86
Width of parasphenoid at occipital cotylus	25
Width of parasphenoid at middle	16
Diameters of anterior face of basihyal:	
Vertical	11
Transverse	27
Width of basibranchial	9
Length of (?) ceratohyal	80"

(?) Genus PYRITOCEPHALUS Fritsch.

Among the specimens collected by Professor Case in Texas there is a small dermal bone (No. 7934 Am. Mus.) ornamented similarly to the cranial bones of *Pyritocephalus* Fritsch as described and figured by that author in his "Fauna der Gaskohle," vol. III, p. 86, pl. 115. It is shown, natural size, in fig. 55. The ornamentation consists of heavy raised lines more or less concentric in arrangement. The single plate is, of course, too fragmentary for specific description; but it is interesting as evidence of the presence in the Texas Permian of another of the forms occurring in the Permian of Bohemia. Professor Fritsch regards *Pyritocephalus* as a typical member of the family *Palæoniscidæ*.

FIG. 55.—Dermal bone of *Pyritocephalus* (?), No. 7934 Am. Mus. Texas.

Genus PLATYSOMUS Agassiz.

Poiss. Fos., II, Pt. 1, 1835, pp. 6, 161.

Revised description of genus:

1. Trunk much deepened.
2. Marginal teeth, small, styliform.
3. Dorsal and anal fins much elongated, the anal somewhat shorter than the dorsal but terminating posteriorly opposite the end of the dorsal; caudal heterocercal with the lower rays elongated so as to make the tail appear equilobate; ventrals small and nearer to anal than to pectorals.
4. Fin-rays articulated, distally subdivided.
5. Fulcra small, usually on all fins.
6. Flank-scales much deepened; ornamented with very fine parallel lines; articulating by peg-and-socket joints; scales gradually decreasing in depth dorsalward, ventralward, and towards the caudal. Ridge-scales present along dorsal and ventral margins; those in front of dorsal and anal smallish, those in front of upper lobe of caudal large.

Platysomus palmaris Cope. (Text fig. 56 and plate 30, fig. 7.)

1891. *Platysomus palmaris*, Cope, Proc. U. S. Nat. Mus., XIV, p. 460, pl. XXXIII, fig. 10.

Type: Numerous fragments, bearing scales, and portions of the pectoral girdle. No. 7281 Am. Mus. Red Beds, Indian Territory.

Referred specimen: An elongated nodule 3 by 9.5 cm., containing a defective fish which exhibits flank scales, caudal fin, and portions of the dorsal and anal. No. 7935 Am. Mus. Texas. (Fig. 56 A.)

This species is inadequately known, having been described from exceedingly fragmentary material. The scales agree most nearly, in size and ornamentation, with those of *Platysomus* and the species may provisionally be left in that genus. In *Benedenius* the scales are not nearly so deep. In the few scales in which the external ornamented layer is preserved, it is seen that the ornament agrees well with that of *Platysomus*, consisting of very fine, parallel, slightly undulating lines, crossing the scale at a slight angle to its vertical axis (plate 30, fig. 7). The flank scales have a depth of about three times their width. Cope's original description may here be quoted.

Original description of species: "The scale-series tend slightly backward from the vertical below, without distinct curvature. The scales on the sides in front are about five times as deep as long, and they graduate in size

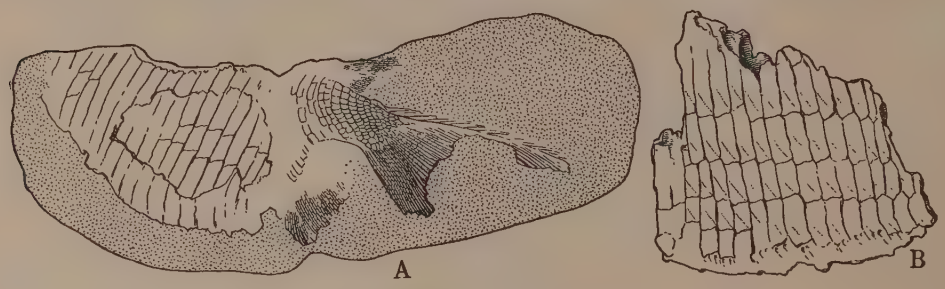

FIG. 56.—*Platysomus palmaris* Cope.

A. Imperfect fish in a nodule, natural size. No. 7935 Am. Mus. Texas.
B. Scales, natural size. One of the fragments representing the type specimen. No. 7281 Am. Mus. Texas.

to the lowest undivided row, where they are about twice as deep as long. The small scales of the inferior row are twice as deep as long, and their depth is about half that of the scales of the next series above them. The sculpture of the scales consists of narrow vertical ridges, which are curved slightly backwards below. About ten may be counted, crossing a transverse bone on each scale. Each of the narrow scales of the inferior row possesses a median angular keel which extends from the anterior edge downwards and backwards, but which does not reach the posterior edge of the scale. The external face of the clavicle is vertically striate like the scales, and horizontally striate on the recurved portion. The interclavicle has more distinct longitudinal ridges, and one ridge on each side of the low median keel is broken up into enamel tubercles.

"The body is acute below. This is always the case, whether the fragments are compressed or not.

"*Measurements.*

	MM
"Diameters of anterior median scale:	
Anteroposterior	2
Vertical	10
Diameters of lowest normal scale:	
Anteroposterior	3
Vertical	4
Depth of scale of inferior border (specimen No. 2)	2.5
Length of interclavicle (specimen No. 3)	10
Width of interclavicle in front (No. 3)	8
Diameter of interclavicular tube, transverse (No. 3)	7"

COMPARISON OF THE PERMIAN FISH-FAUNA OF AMERICA AND BOHEMIA.

In the accompanying table the Permian fishes of Illinois, Texas, and Bohemia are brought together for comparison. It is seen that of the two American localities the Texan is the richer in genera—12 as against 6 for Illinois. The Illinois fauna is entirely represented in Texas with the exception of one group—the *Petalodontidæ*, a family of sharks represented in Illinois by the genus *Janassa;* but as this genus is known only from small teeth, which may easily be overlooked in collecting, it is probable that it may yet be discovered in the Texan formations. However this may be, there is a remarkable agreement between the two faunas considering the distance by which they are separated.

Table showing Genera of Fishes in the Permian of Illinois, Texas, and Bohemia.

	Bohemia[1]	America.	
		Texas.	Illinois.
ACANTHODII:			
Traquairia.....	×	...	...
Protacanthodes ..	×	...	...
Acanthodes.....	×	...	...
ICHTHYOTOMI:			
Pleuracanthus.... (Orthacanthus, Xenacanthus)	×	...	×
Diacranodus.....	...	×	...
SELACHII:			
Hybodus.....	×	×	...
Janassa.....	...	...	×
ICHTHYODORULITES:			
Ctenacanthus..	...	×	...
Tubulacanthus...	×	...	...
Brachiacanthus ..	×	...	...
Anodontacanthus	×	×	...
DIPNEUSTI:			
Sagenodus.....	×	×	×
Ceratodus.....	...	×	...
Gnathorhiza.....	...	×	×
CROSSOPTERYGII:			
Megalichthys....	×	×	...
ACTINOPTERI:			
Sphærolepis.....	×	×	×
Acentrophorus..	×	...	...
Spermatodus.....	...	×	...
Pyritocephalus...	×	?	...
Sceletophorus....	×	...	...
Phanerosteon.....	×	...	...
Amblypterus.....	×	...	...
Acrolepis.....	×	...	...
Progyrolepis.....	×	...	...
Platysomus.....	...	×	×
	18	11 (12?)	6

[1] Based on the list given by Fritsch in Sitzungsb. d. k. böhm, Gesell. Wiss., 1895, pp. 12 *et seq.*

A comparison of the Permian faunas of Texas and Bohemia brings out several interesting points. While the groups represented in the two are, with the exception of the *Acanthodii*, the same, there is a marked difference in the genera respectively represented, proving the long segregation of the two stocks from which the Permian faunas of the two localities are descended. The most remarkable difference between the faunas is the presence of *Acanthodii* (three genera) in Bohemia and their absence in Texas. The *Acanthodii* occur in Bohemia at the same level as *Pleuracanthus*, a horizon which may be correlated approximately with the Texas and Illinois horizons.

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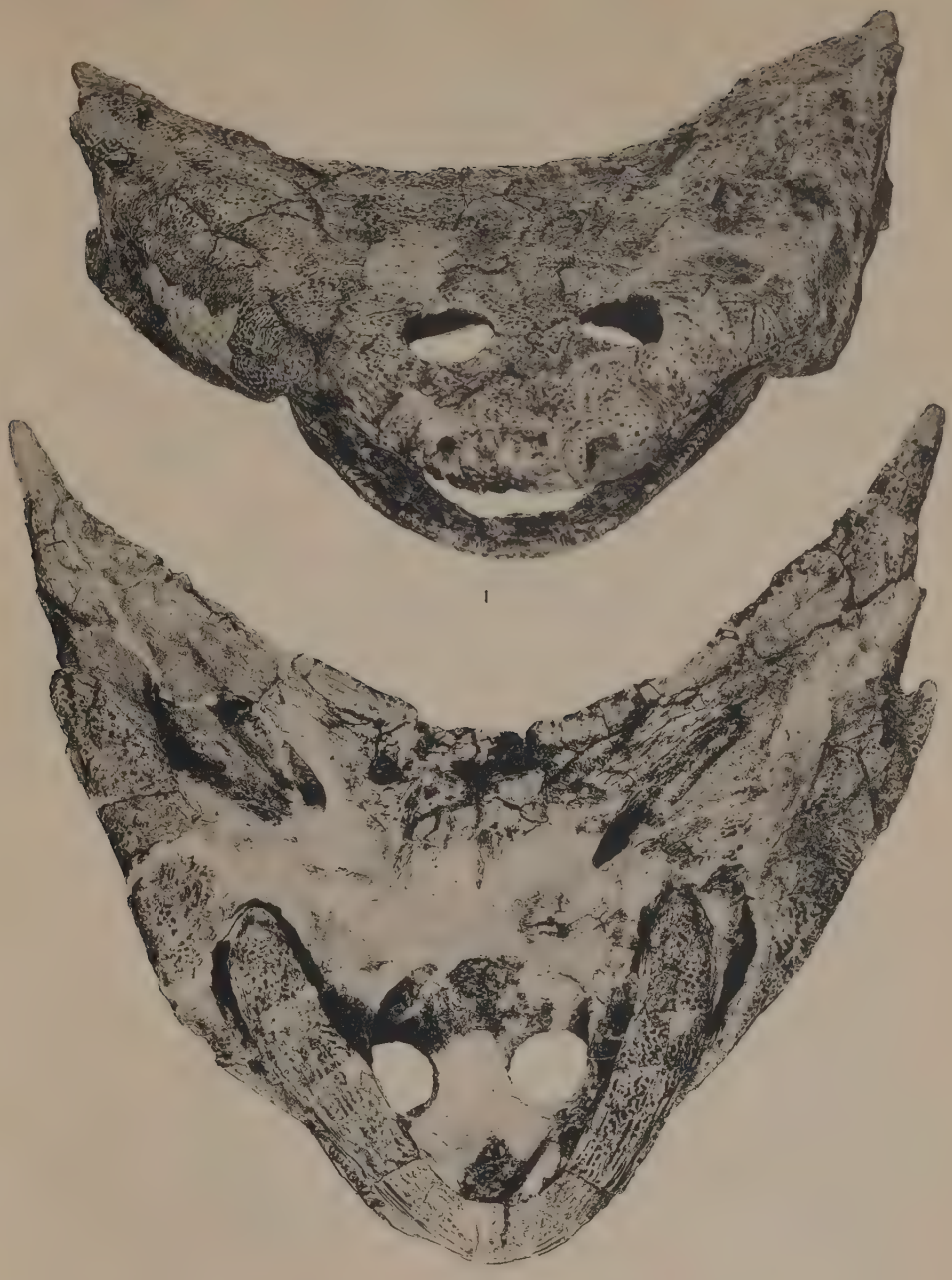
Diplocaulus limbatus. No. 4470 Am. Mus. × ⅔.

1. The Skull.

2, 3, 4. Dorsal vertebrae. 2, from side; 3, from above; 4, from below.

Diplocaulus magnicornis. No. 4472 Am. Mus. × ½.

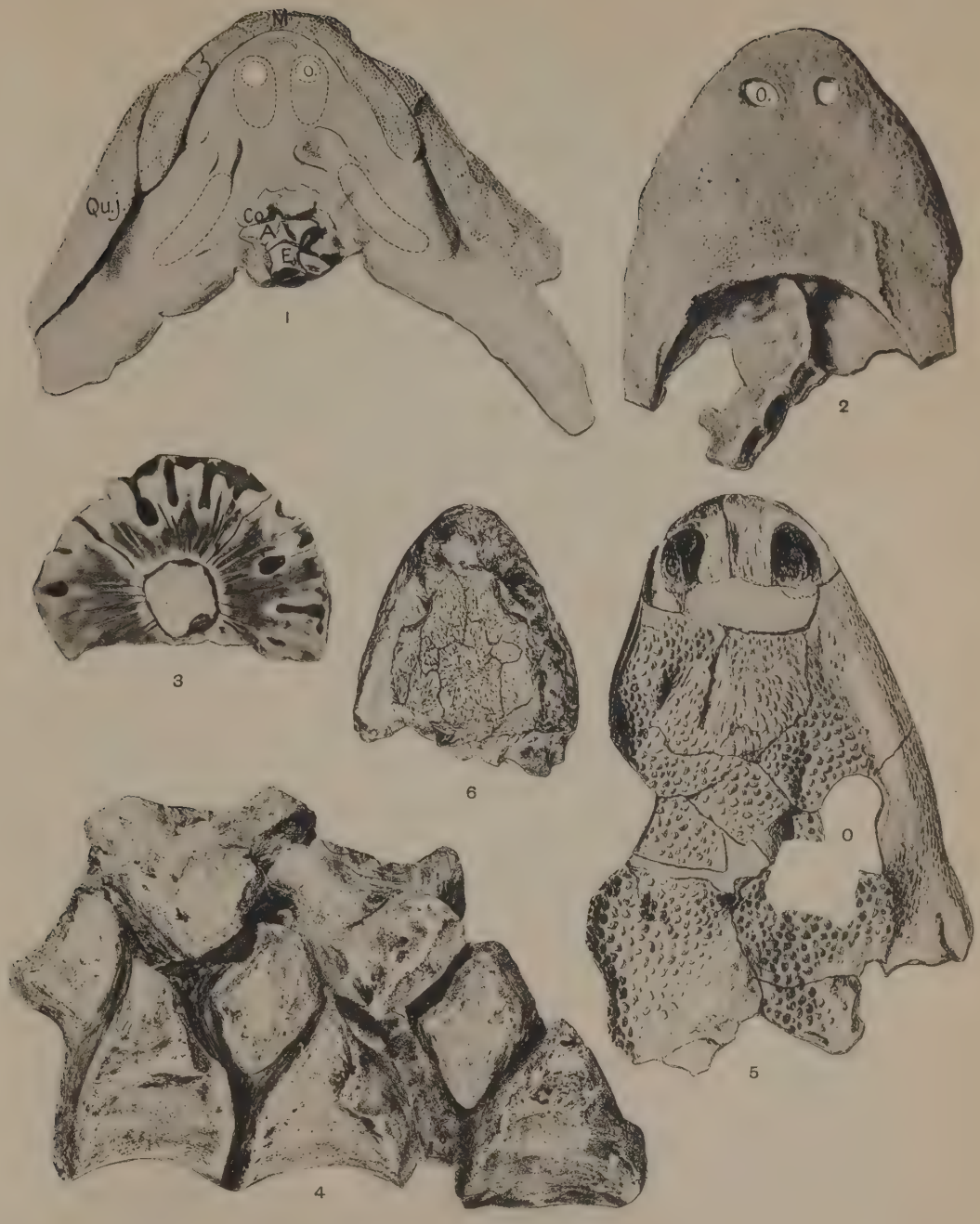


1

2

Diplocaulus magnicornis. No. 4514 Am. Mus. × 1.
1, anterior view of skull; 2, lower surface.

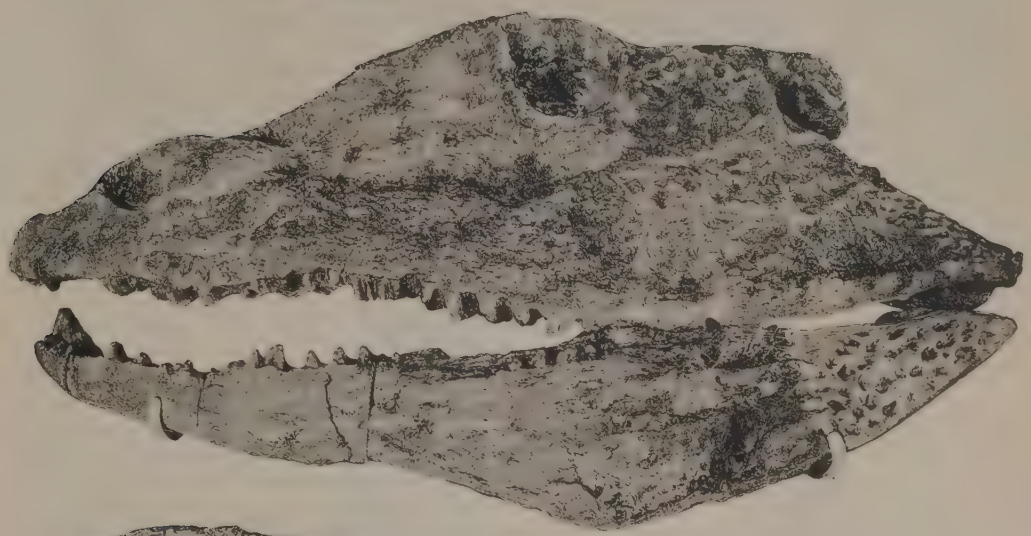
1. *Diplocaulus magnicornis*. No. 4467 Am. Mus. × ⅘. Lower surface of skull showing teeth.
2. *Eryops megacephalus*. No. 4186 Am. Mus. × ⅔. Upper surface of a particularly broad skull.



1 and 2. Skulls of *Diplocaulus copei*. Reduced about half.
co, occipital condyle.
3. Cross-section of a tooth of *Eryops*. Enlarged.
4. Dorsal vertebrae of *Eryops*. × 1.
5. Skull of *Aspidosaurus chiton*. × 1.
6. Skull of *Trimerorhachis conangulus*. × 1.

Eryops megacephalus. No. 4188 Am. Mus. × ⅜. Lower surface of a skull.

3



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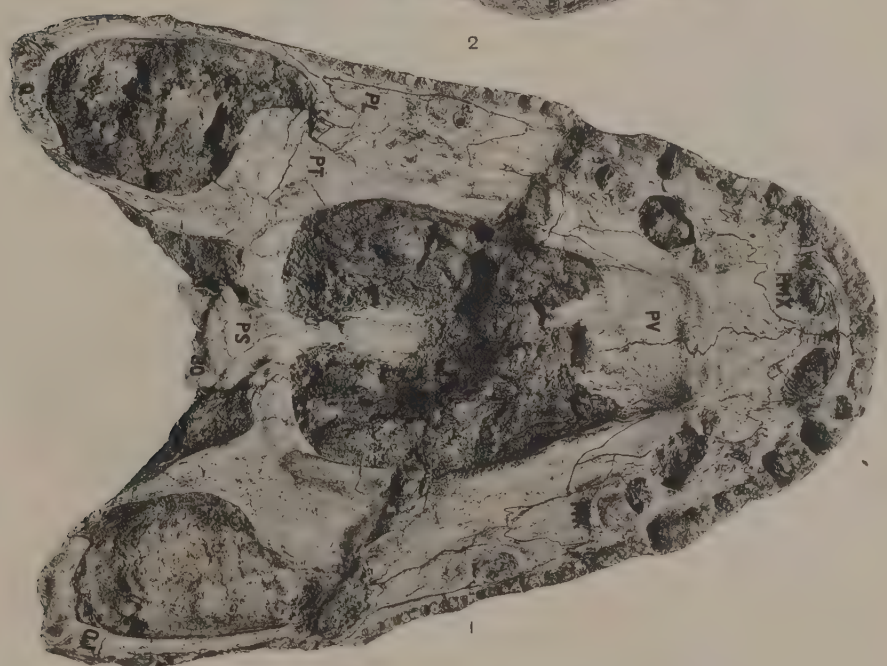

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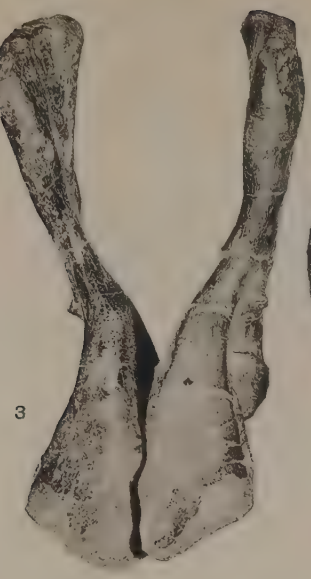
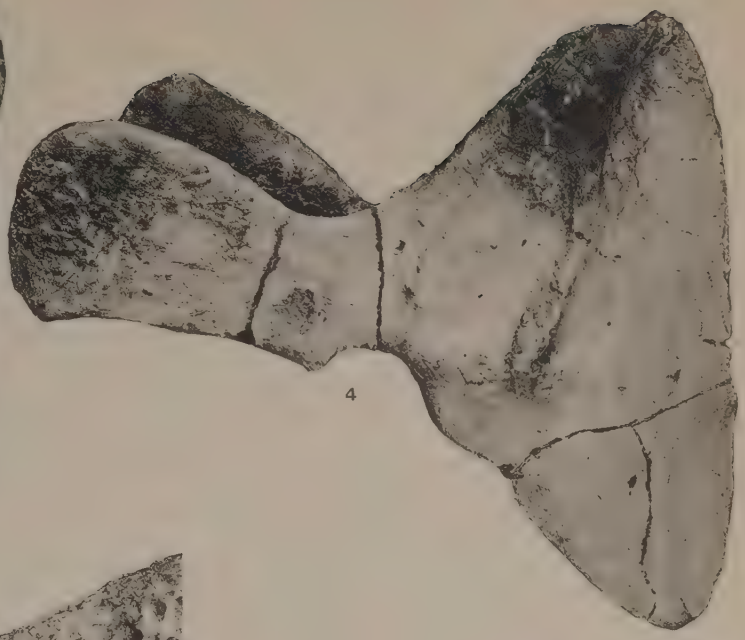
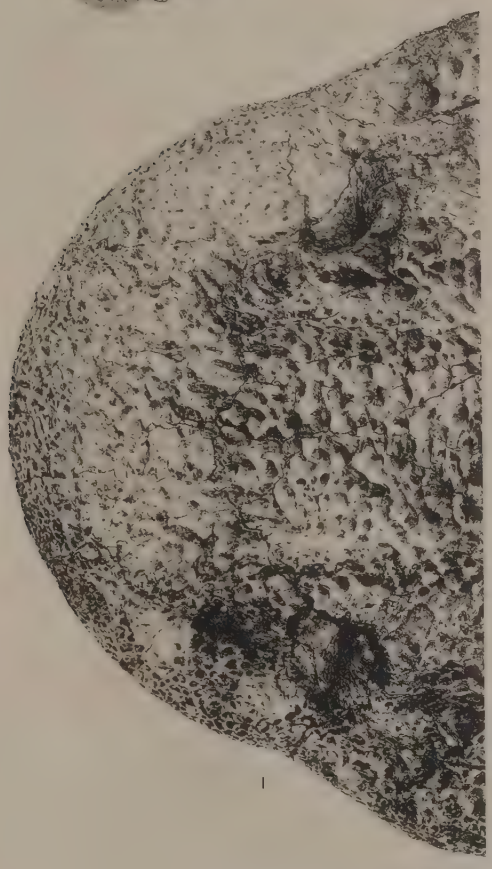
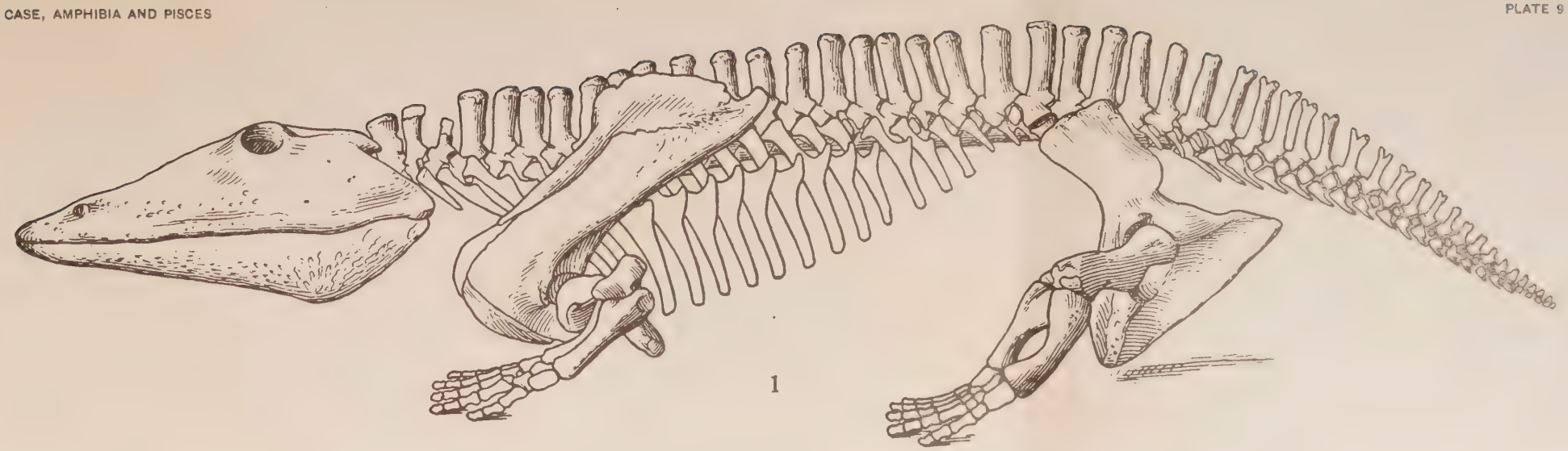
1. *Eryops megacephalus*. No. 4673 Am. Mus. × ⅓. Palatal surface of a skull, showing the sutures.
2. *Eryops megacephalus*. No. 4180 Am. Mus. × ⅛. Lateral view of a well preserved skull.
3. *Eryops megacephalus*. No. 4313 Am. Mus. × ½. Outer surface of right lower jaw.







1. *Eryops megacephalus*. No. 4673 Am. Mus. × ⅛. Anterior portion of nose, showing sculpture.
2. *Eryops* (?). No. 4310 Am. Mus. × ⅔. Upper surface of skull of a young individual.
3. *Eryops megacephalus*. No. 4183 Am. Mus. × ⅛. Anterior view of pelvis.
4. *Eryops megacephalus*. No. 4582 Am. Mus. × ¼. Lateral view of pelvis.



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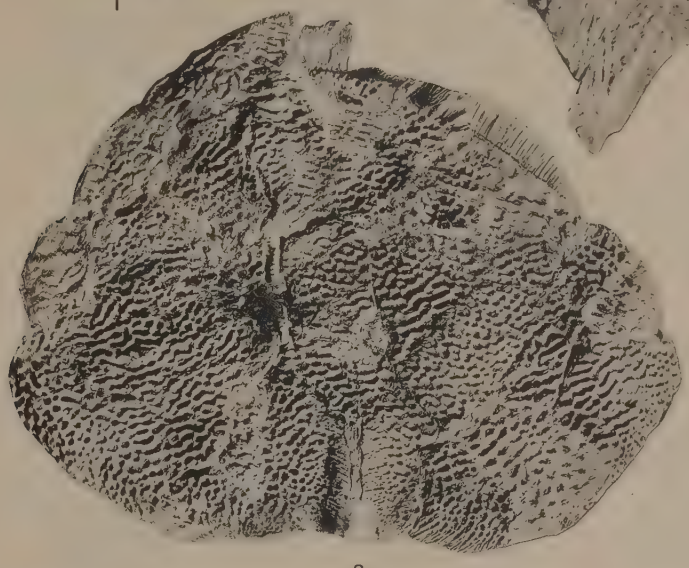
1. *Eryops megacephalus.* Restoration of specimen No. 4893 Am. Mus. × $\frac{1}{6}$.
2. Anterior view of clavicular arch, showing interclavicle, clavicles and scapulæ. No. 4186 Am. × $\frac{1}{3}$.
3. Scapula and cleithrum of right side. No. 4893 Am. Mus. × $\frac{1}{3}$.
4. Upper view of left forefoot. No. 4186 Am. Mus. × $\frac{1}{3}$.
5. Lower view of same foot shown in 4.

E. megacephalus. Sketch model restoration showing author's idea of general form of *Eryops*.
1, side view; 2, upper view.

Acheloma cumminsi. No. 4205 Am. Mus. × ⅜ circa.

1

2



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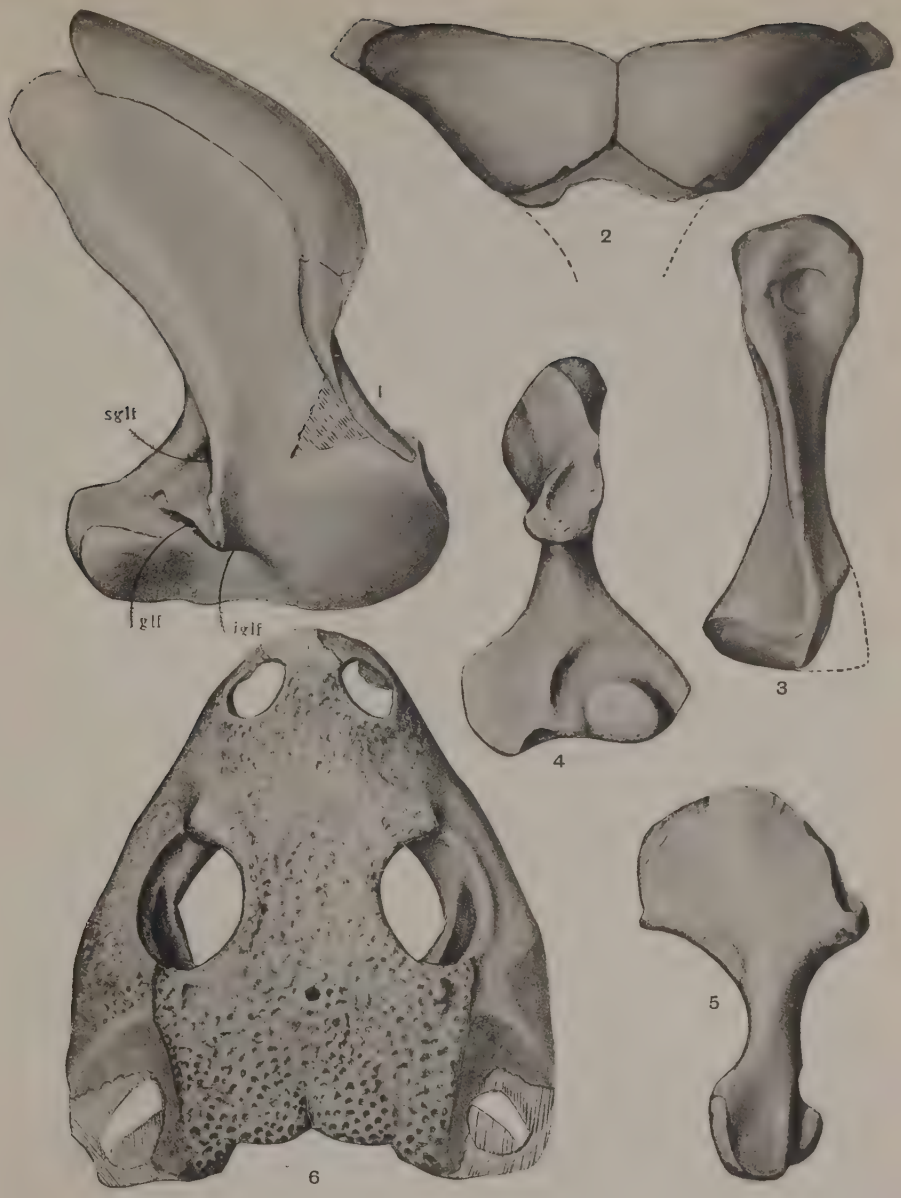
4

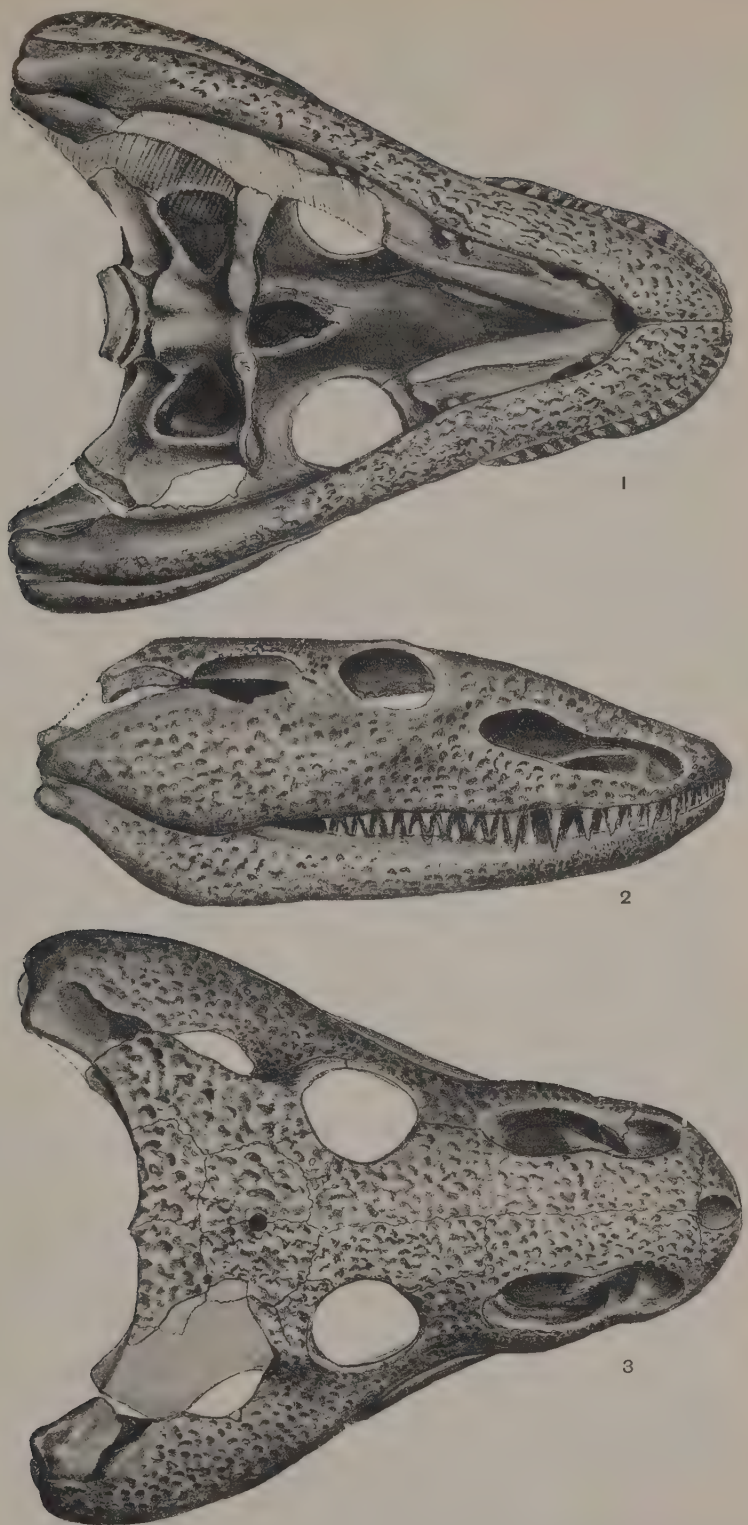
1. *Trimerorhachis mesops*. × ⅘. Anterior end of skull from above.
2. Interclavicle of *Trimerorhachis* (?). × ⅘.
3. *Diplocaulus magnicornis*. × ⅘. Clavicles and interclavicle in position.
4. *Trimerorhachis insignis*. × ⅘. Outer surface of right half of lower jaw.



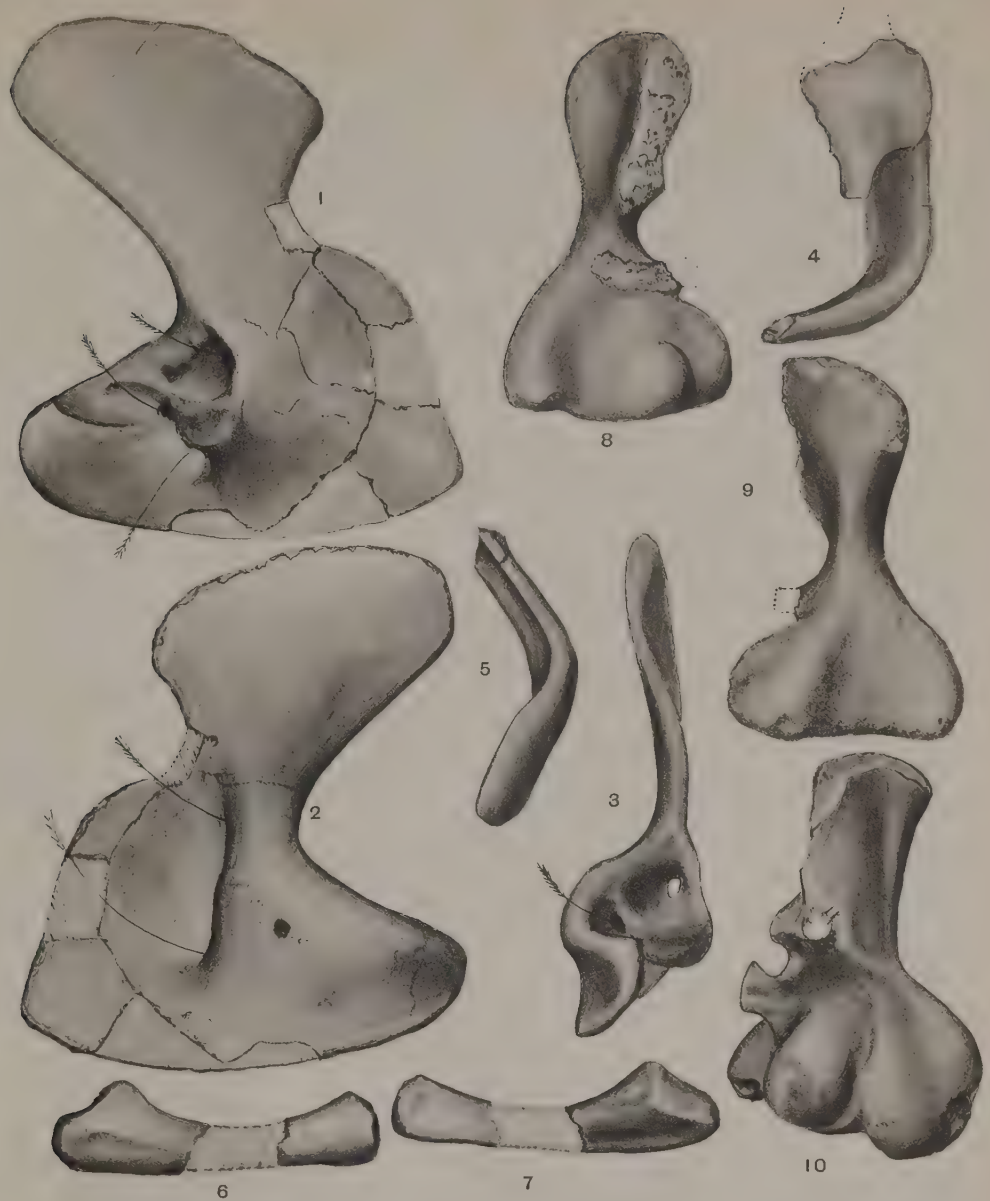
Dissorophus multicinctus. No. 648 Univ. of Chicago. 1-5, × ⅘; 6, × ⅜.

1. Right scapula-corocoid with cleithrum, from outer side. *sglf*, supraglenoid foramen; *glf*, glenoid foramen; *iglf*, infraglenoid foramen.
2. Clavicles and interclavicle from below.
3. Right femur, from below.
4. Left humerus, posterior view.
5. Left humerus, inner side.
6. Skull.

All figures after Williston.

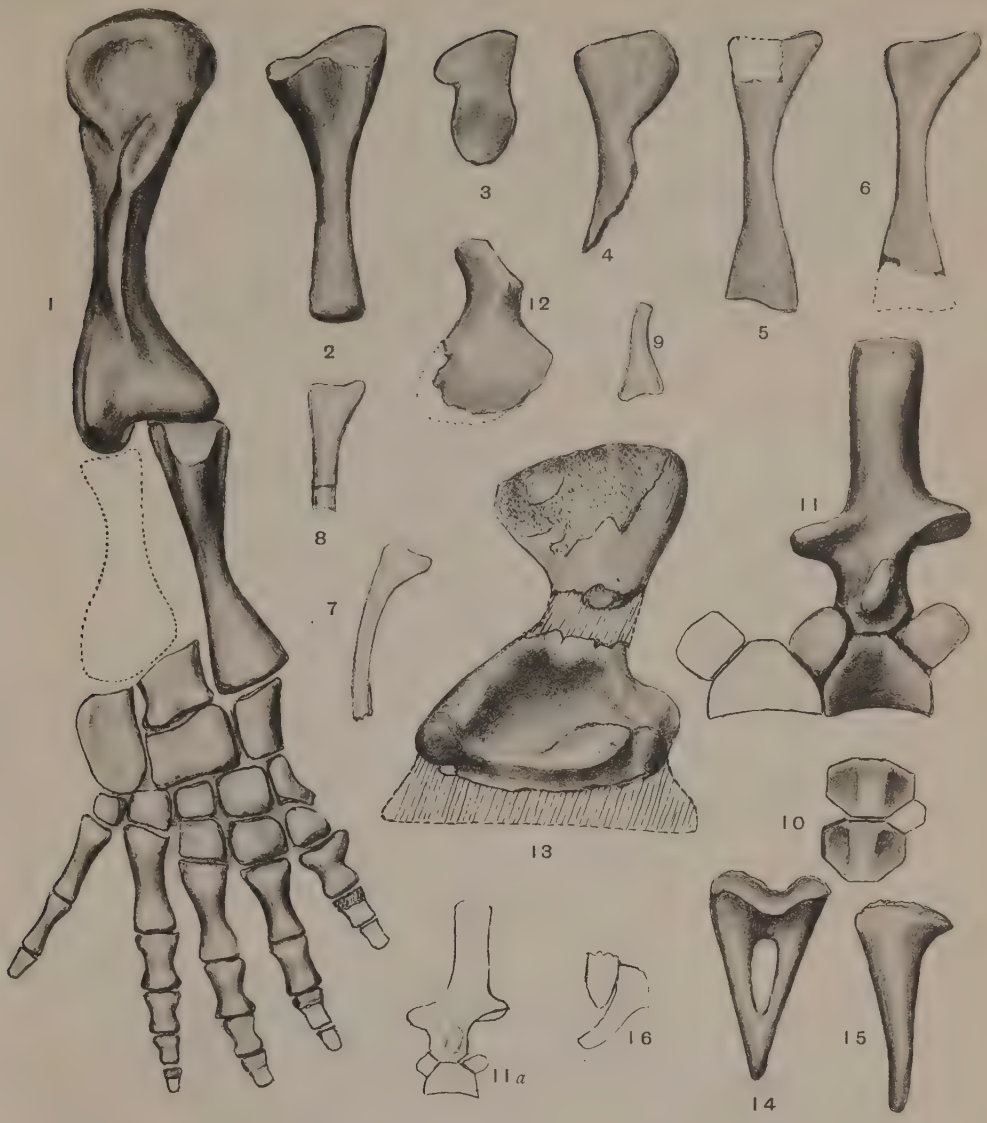


Trematops milleri. No. 640 Univ. of Chicago. × ½. All figures after Williston.
1, lower surface of skull; 2, lateral view of skull; 3, upper surface of skull.



Trematops milleri. No. 640 Univ. of Chicago. × ⅘. All figures after Williston.

1. Right scapula-corocoid, outer surface.
2. The same, inner surface.
3. The same, posterior edge.
4. Interclavicle and right clavicle from above.
5. Right clavicle, from behind.
6. Left ulna, inner surface.
7. The same, outer surface.
8. Left humerus, anterior view.
9. The same, posterior view.
10. Right humerus of *Eryops*, inserted for comparison.

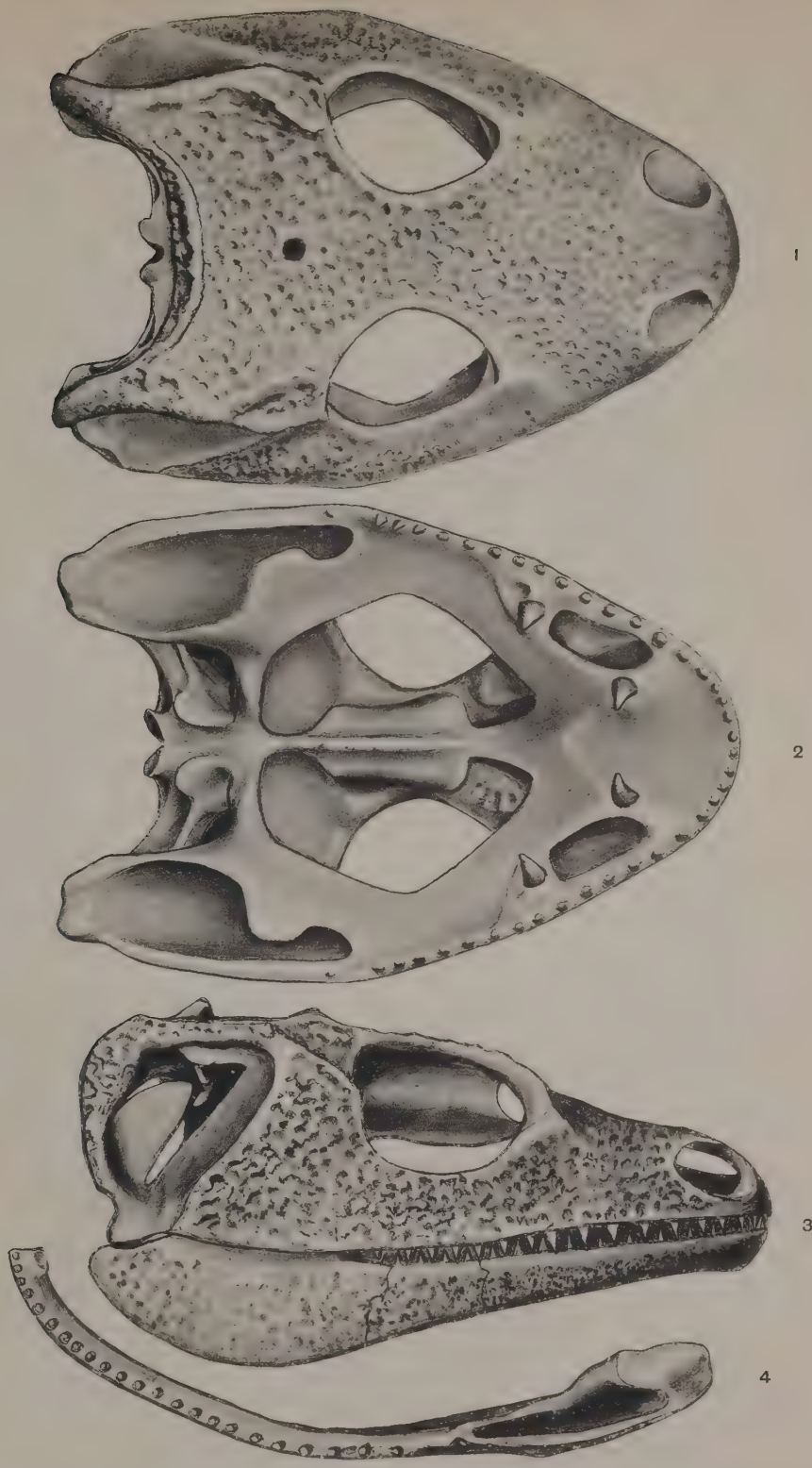


Trematops milleri. No. 640 Univ. of Chicago. × ⅛. All figures after Williston.

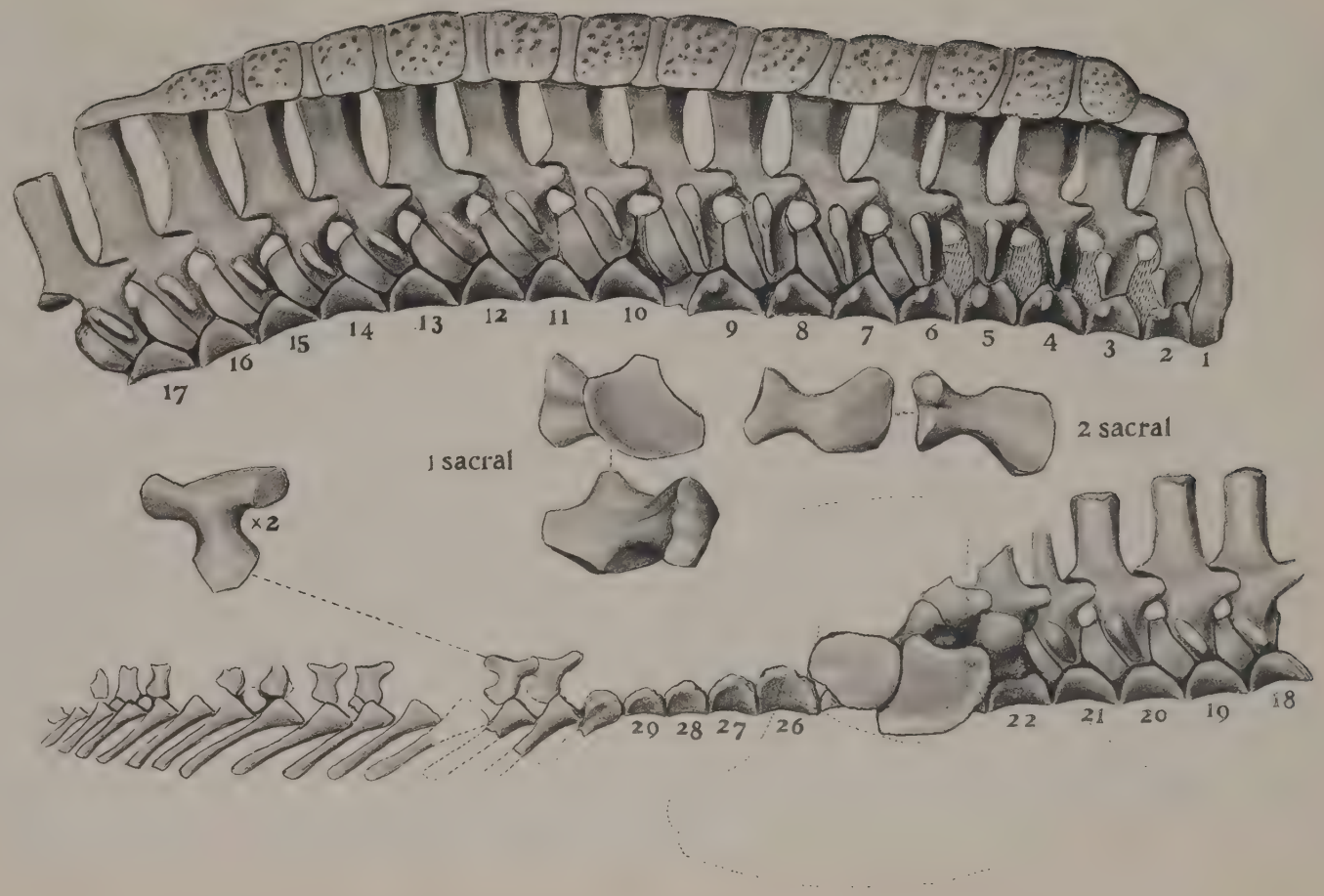
1. Left hind leg, lower surface.
2. Left tibia, outer surface.
3. The same, upper articular surface.
4. Second rib, from the right side.
5. Seventh rib, right side.
6. Eighth rib, right side.
7. Seventeenth rib, right side.
8. Nineteenth rib, right side.
9. Twenty-third rib, right side.
10. Twelfth and thirteenth hypocentra, from below.
11. Ninth vertebra, from the side, nearly natural size.

11a. The same, on same scale as the other figures.

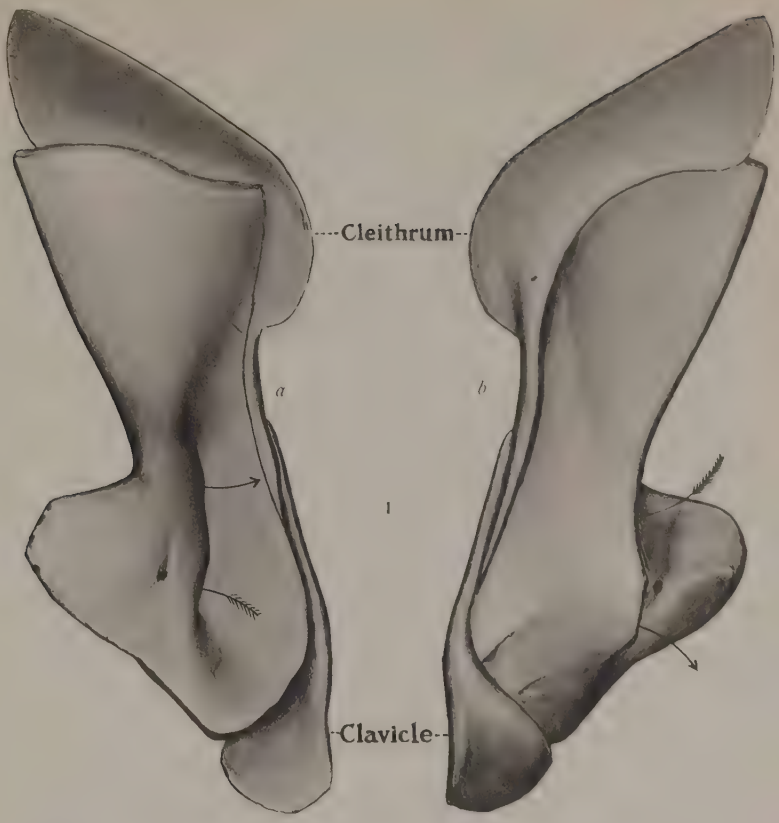
12. Left sacral rib, from above.
13. Left half of the pelvis, outer surface.
14. A chevron bone, posterior surface.
15. The same, from the side. The last two figures nearly natural size.

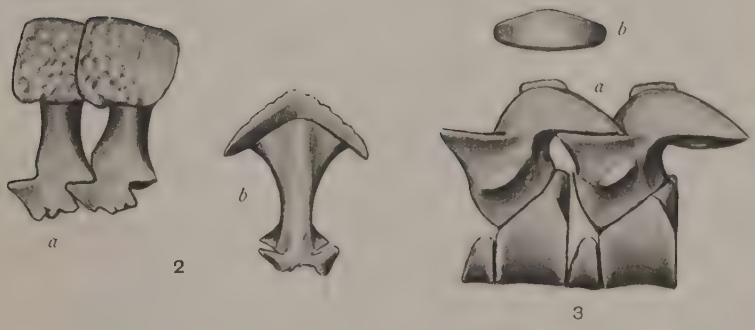


Cacops aspidephorus. No. 647 Univ. of Chicago. × ½. All figures after Williston.
1. Upper view of skull. 2. Lower view of skull. 3. Lateral view of skull. 4. Upper surface of lower jaw.



Cacops aspidephorus. No. 647 Univ. of Chicago. × ¾. Dorsal and caudal vertebrae.
All figures after Williston.





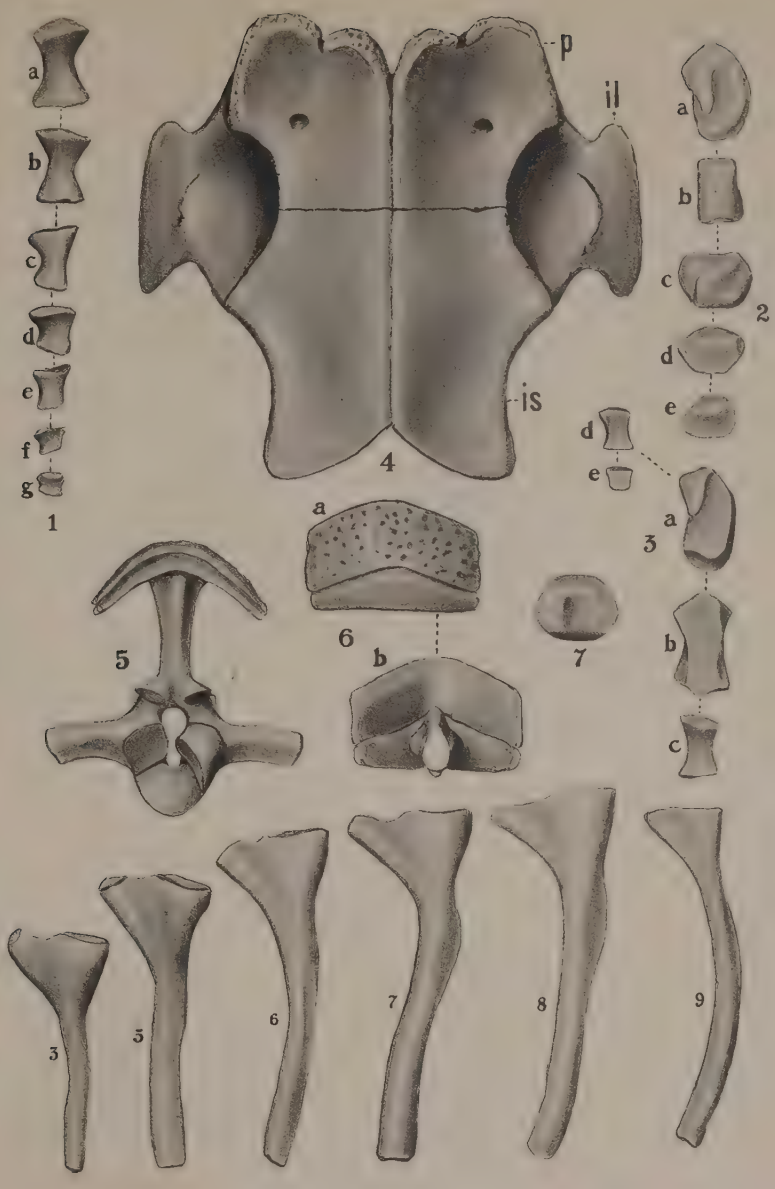
1. *Cacops aspidephorus*. No. 647 Univ. of Chicago. × ⅔. Scapula with attached cleithrum and clavicle; *a*, inner surface; *b*, outer surface.
2. *Aspidosaurus*. × ⅜. Spines of dorsal vertebrae; *a*, from the left side; *b*, from in front.
3. *Desmospondylus anomalus*. × ⅜. Posterior dorsal vertebrae; *a*, from the left side; *b*, intercentrum from below.

All figures after Williston.

Cacops aspidephorus. No. 647 Univ. of Chicago. × ⅔.

1. Pectoral girdle, upper surface.
2. Left humerus, inner side.
3. The same, outer side.
4. The same, anterior view.
5. The same, posterior view.

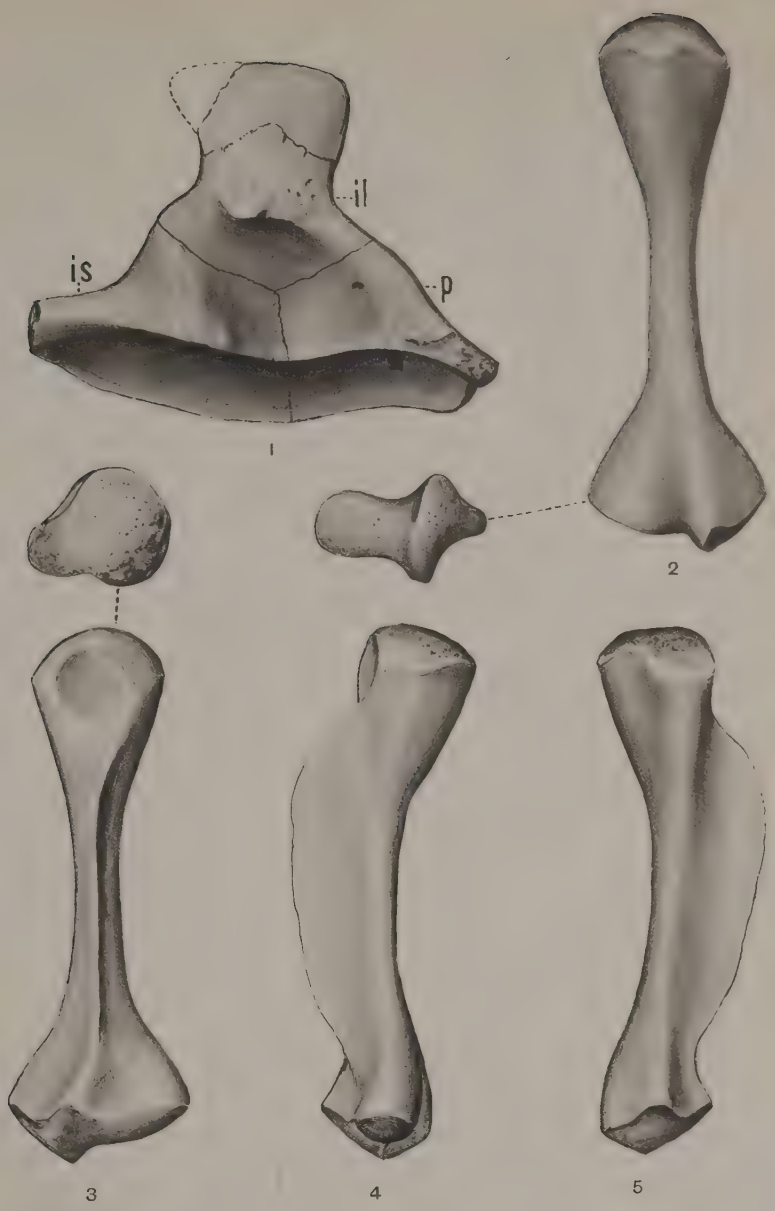
All figures after Williston.



Cacops aspidephorus. No. 647 Univ. of Chicago. × ⅔.

1. Various toe bones from the left hind foot.
2. Tarsals of the same foot.
3. Carpals and phalanges of the left hind foot.
4. Lower surface of the pelvis.
5. The twelfth vertebra, anterior view, the left pleurocentrum omitted.
6. The dorsal shield of the same vertebra; *a*, from above, *b*, from below.
7. Intercentrum.
8. Ribs, as numbered; three and five from the left side, the others from the right.

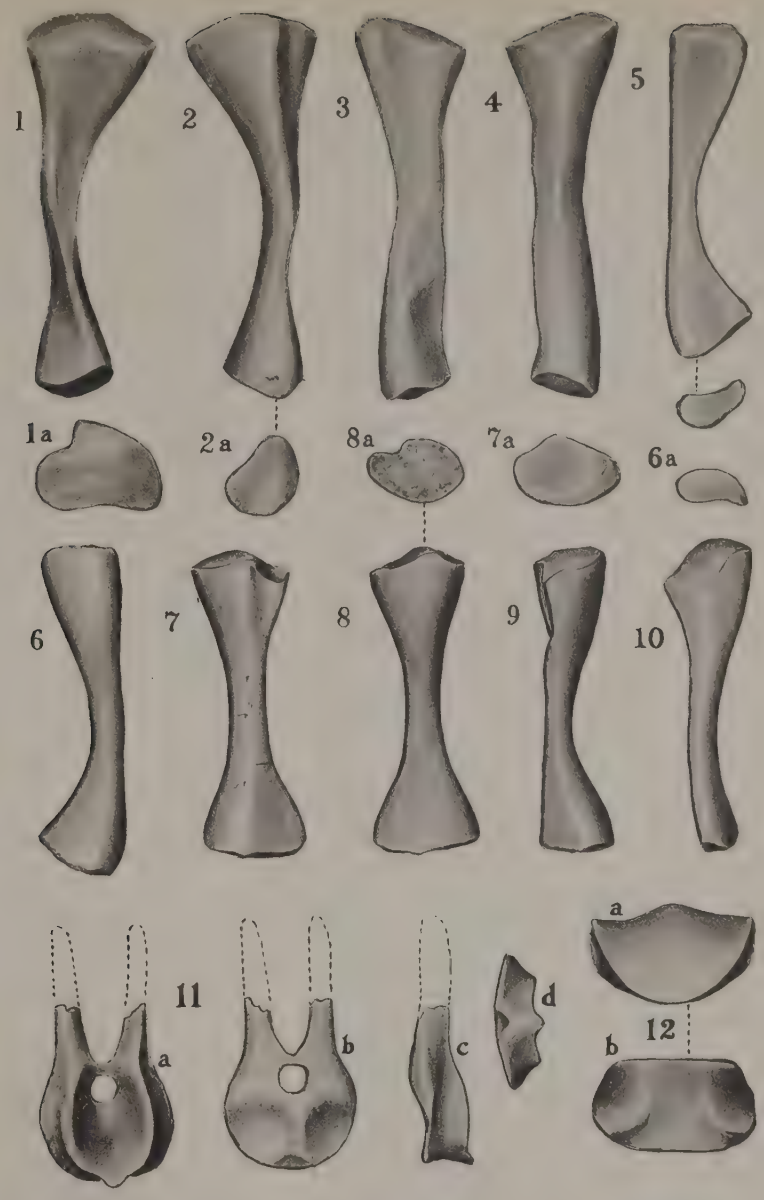
All figures after Williston.



Cacops aspidephorus. No. 647 Univ. of Chicago. × ⅔.

1. Outer surface of the pelvis, from the right side.
2. Left femur, anterior view.
3. The same, posterior view.
4. The same, inner surface.
5. The same, outer surface.

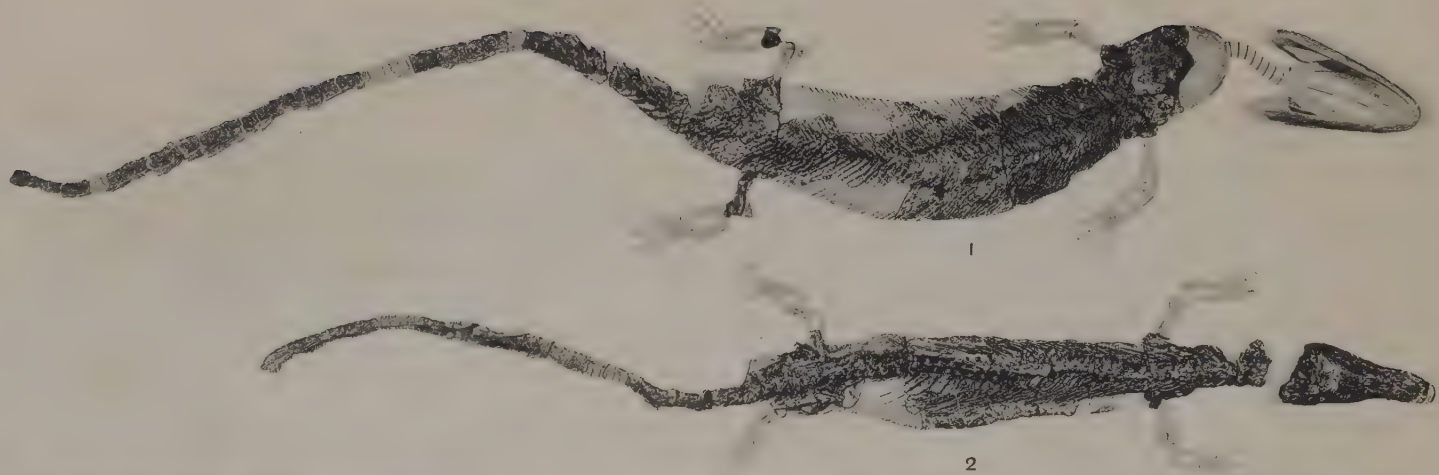
All figures after Williston.



1-10, *Cacops aspidephorus*. No. 647 Univ. of Chicago. × ⅔. 11, 12, *Dissorophus multicinctus*.

1. Left tibia, anterior view.
2. The same, posterior view.
3. The same, inner surface.
4. The same, outer surface.
5. Left fibula, posterior view.
6. The same, anterior view, *a*, upper extremity.
7. Left radius, posterior view.
8. The same, anterior view.
9. The same, inner surface.
10. Left ulna, anterior view.
11. Atlas; *a*, from behind; *b*, from in front; *c*, from the side; *d*, from below.
12. The same, anterior intercentrum. × ⅔.

All figures after Williston.

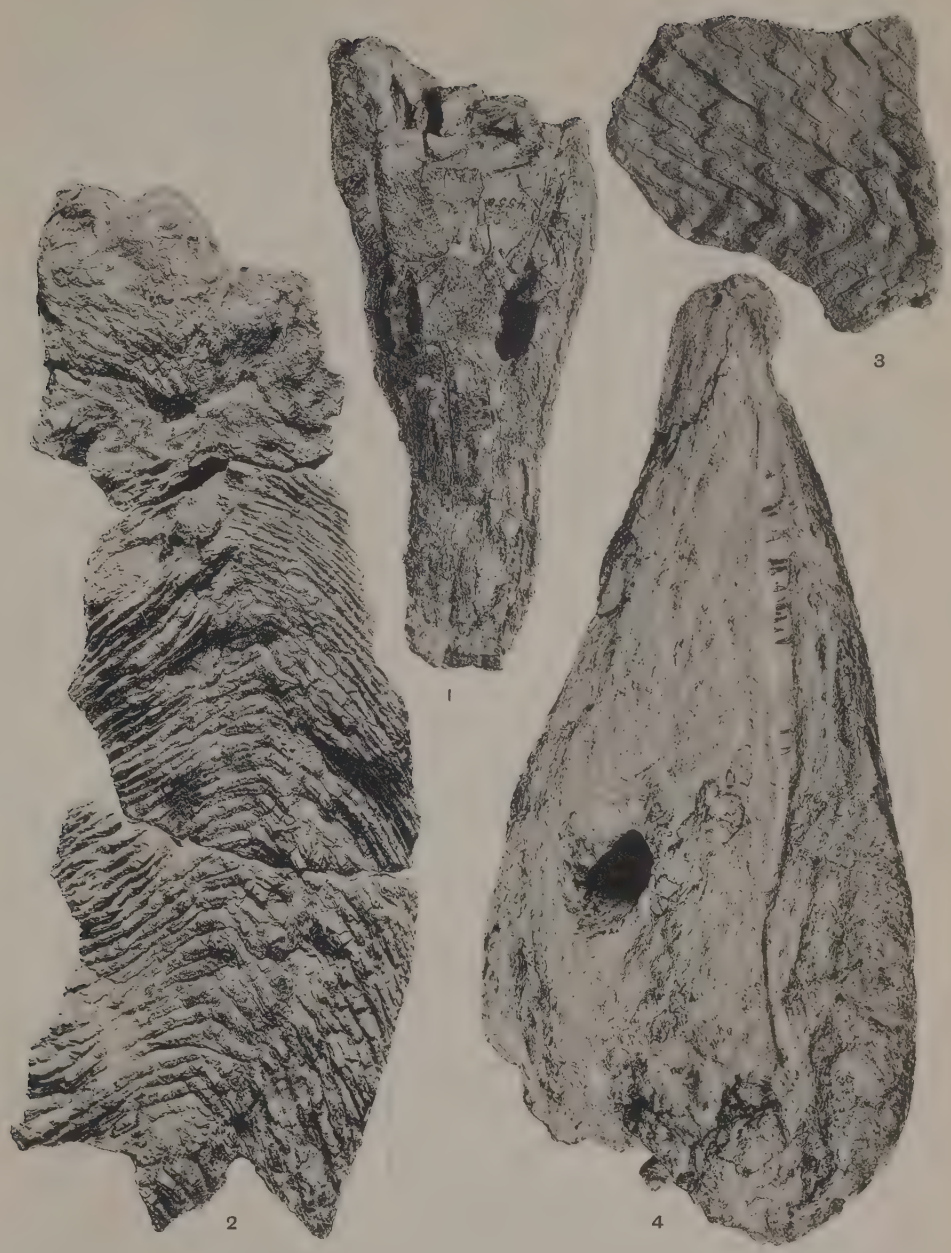


1

2

3

1 and 2. Two skeletons of *Cricotus heteroclitus*. Nos. 4550 and 4550*a* Am. Mus. Restored in considerable measure.



1. Skull of *Cricotus heteroclitus*. No. 4550*a*. × ½.
2. Abdominal armor of *Cricotus heteroclitus*. No. 4550*a* Am. Mus. × ⅜.
3. A fragment of the abdominal armor of *Cricotus*. × ¾.
4. Skull of *Cricotus heteroclitus*. No. 4551 Am. Mus. × ½.

1, 1*a*, 1*b*. *Janassa strigilina*, front, posterior, and side views. Type. × 3. No. 6500 Univ. of Chicago.
2, 2*a*, 2*b*. *Janassa gurleyana*, front, posterior, and side views. Type. × 3. No. 6501 Univ. of Chicago.
3, 3′, 3*a*, 3*b*, Fragmentary head spines of *Pleuracanthus quadriseriatus*, ventral view; × 3. 3*a*, 3*b*, sections taken at levels indicated in figs. 3, 3′. No. 6502 Univ. of Chicago.
4, 4′, 4*a*, 4*b*, Fragmentary head spines of *Pleuracanthus gracilis* Newb., ventral view. × 3. 4*a*, 4*b*, sections taken at levels indicated in figs. 4, 4′. No. 6503 Univ. of Chicago.
5, 5*a*, 5*b*. *Anodontacanthus americanus* n. sp. × 2. Type. No. 7934 Am. Mus. Texas. 5*a*, 5*b*, sections taken at levels indicated in fig. 5.
6. *Sagenodus dialophus*. Left lower dental plate. Type. × 1⅓ No. 7234 Am. Mus.
7. *Sagenodus dialophus*. Dental plate, × 1⅓. No. 7470 Am. Mus.
8-11. *Sagenodus fossatus*. × 1⅓. 8, Immature left mandibular plate. Type. No. 6506 Univ. of Chicago. 9, Incomplete upper dental plate. Type of *Ctenodus gurleyanus* Cope. No. 6509 Univ. of Chicago. 10, 10*a*, Lower dental plate. Type of *Ctenodus porrectus* Cope. No. 7235 Am. Mus. 11, Lower dental plate. Type of *Ctenodus vabasensis* Cope. No. 6510 Univ. of Chicago.

1-3. *Sagenodus fossatus*, dental plates, × 1½. Am. Mus.: original of figs. 1, 1*a*, No. 7475; originals of 2 and 3, No. 7260.

4, 4*a*. *Sagenodus paucicristatus*. Dental plate, × 1½ Type. No. 6505 Univ. of Chicago.

5, 5*a*. *Sagenodus periprion*. Left palatal plate, × 1½. Type. No. 7474 Am. Mus.

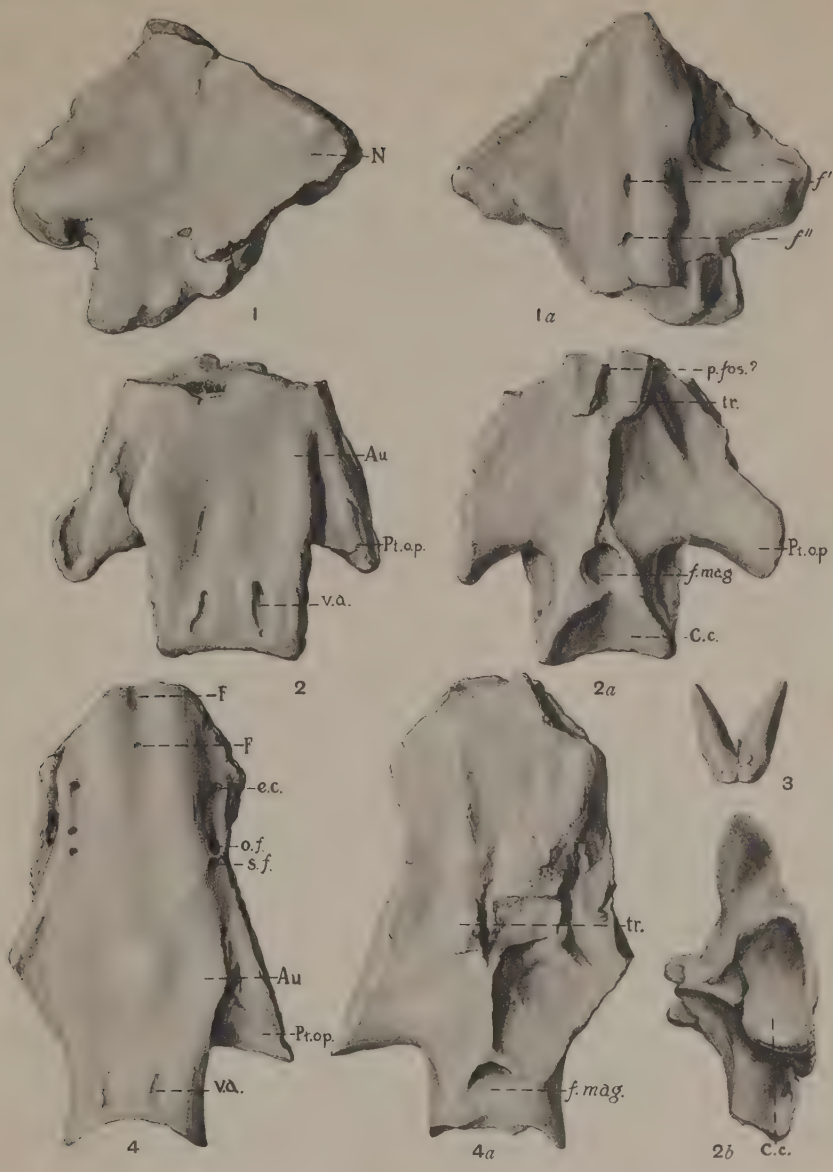
6. *Sagenodus heterolophus*?. Incomplete dental plate, × 1½. No. 7473 Am. Mus.

7, 7*a*, 8. *Sagenodus vinslovi*. Left palatal plates, × 1½. Type. 7, 7*a*. No. 6507 Univ. of Chicago. 8. A specimen from Texas; No. 7233 Am. Mus.

9, 9*a*. Side and top views of the type of *Gnathorhiza serrata*, No. 7258 Am. Mus. × 3.

10. Top view of *Gnathorhiza pusilla*. Type. No. 6508 Univ. of Chicago. × 3.

11, 11a. *Ceratodus favosus*. Imperfect dental plate attached to a fragment of the splenial, × 1½. Type. 11, seen from above; 11*a*, viewed from side. No. 7230 Am. Mus.



Diacranodus texensis (Cope). × ⅔. Texas.

1. Anterior portion of a cranium, viewed from above. Cotype. No. 7929 Am. Mus.

1a. The same viewed from below.

2. Posterior half of a cranium, viewed from above. Cotype. No. 7930 Am. Mus.

2*a*. The same seen from below.

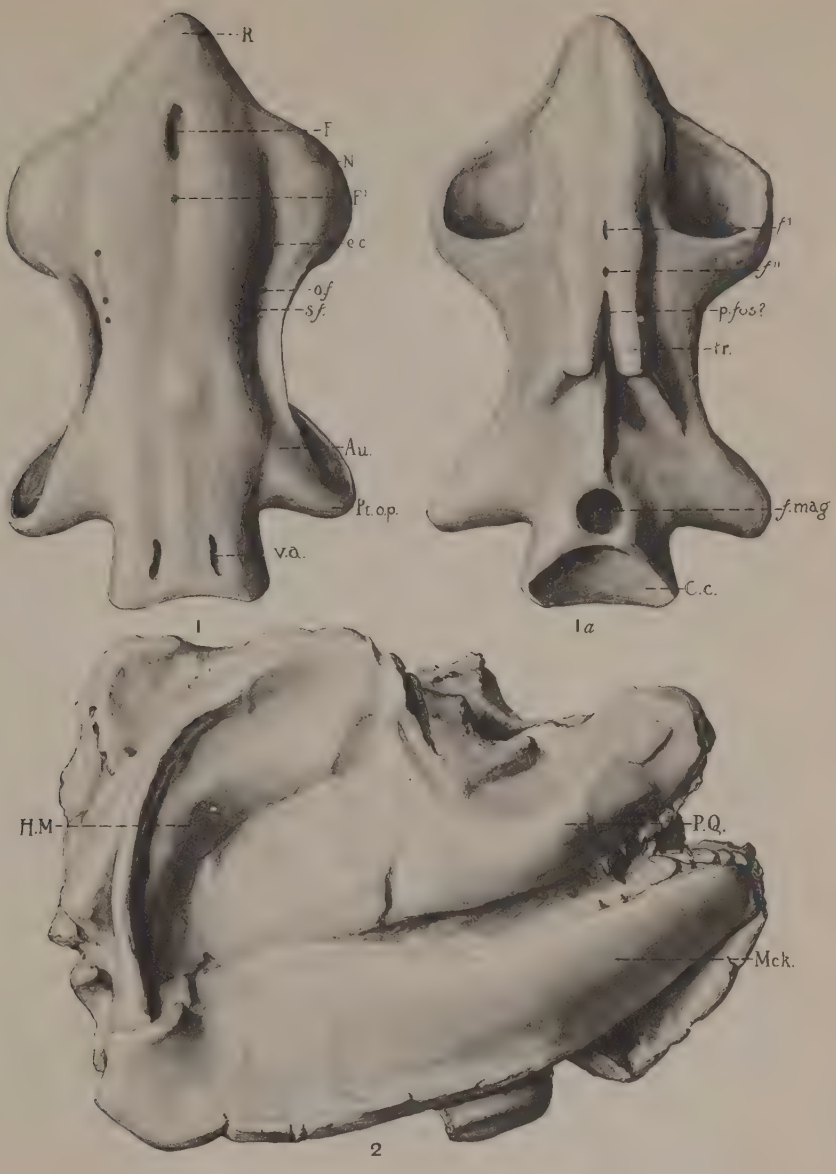
2*b*. The same in posterior view.

3. Tooth, probably of this species.

4. Nearly complete cranium seen from above. No. 7931 Am. Mus.

4*a*. The same seen from below.

au, auditory capsule; *C.c.*, cotyloid cavity for articulation of occipital spine; *e.c.*, ethmoid canal; *F*, *F*[1], fontanelles; *f. mag.*, foramen magnum; *o. f.*, opthalmic foramen; *Pt. o.p.*, postorbital process; *p. fos.?*, pituitary fossa?; *s.f.*, supraorbital foramen; *tr.*, trabecula; *v. a.*, vestibular aqueduct.

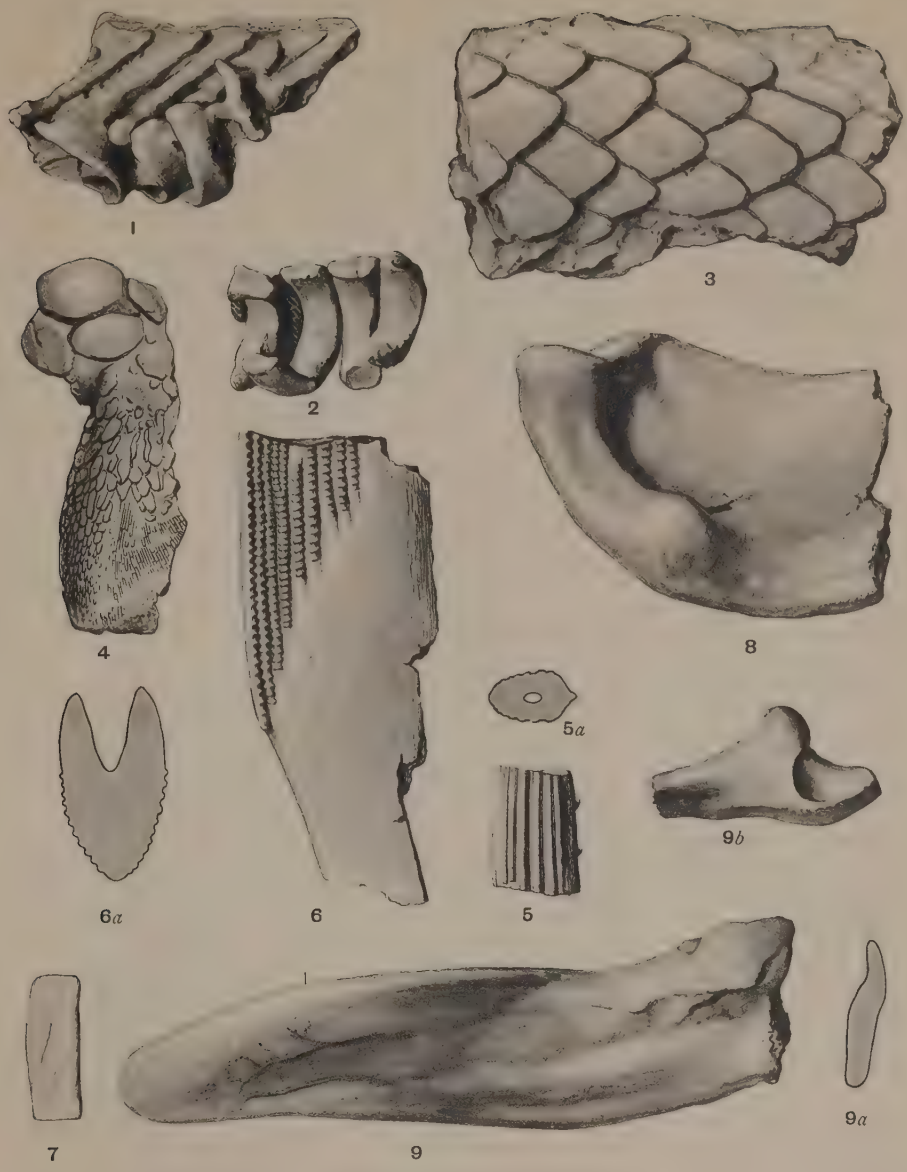


Diacranodus texensis (Cope). × ⅔. Texas.

1, 1a. Restoration of the cranium, viewed from above and below.

2. Specimen exhibiting the jaws in natural articulation. Cotype. No. 7117 Am. Mus.

au, auditory capsule; *C.c.*, cotyloid cavity for articulation of cranial spine; *e.c.*, ethmoid canal; *F*, *F*¹, fontanelles; *f'*, *f''*, foramina; *f. mag.*, foramen magnum; *H.M.*, hyomandibular; *Mck.*, meckelian cartilage; *N.*, nasal capsule; *o.f.*, opthalmic foramen; *P.Q.*, palatoquadrate; *p.fos*?, pituitary fossa?; *Pt.o.p.*, postorbital process; *R.*, rostrum; *s.f.*, supraorbital foramen; *tr.*, trabecula; *v.a.*, vestibular aqueduct.



1-4. *Megalichthys nitidus* (Cope); natural size. Texas.
1. Vertebrae with neural spines.
2. Incomplete vertebral rings.
3. Flank scales of type specimen. No. 7239 Am. Mus.
4. Pectoral fin of type specimen. No. 7239 Am. Mus.

5, 5*a*. Fragment of a spine belonging to (?) *Hybodus*. × 1⅓. Texas. No. 7263 Am. Mus.

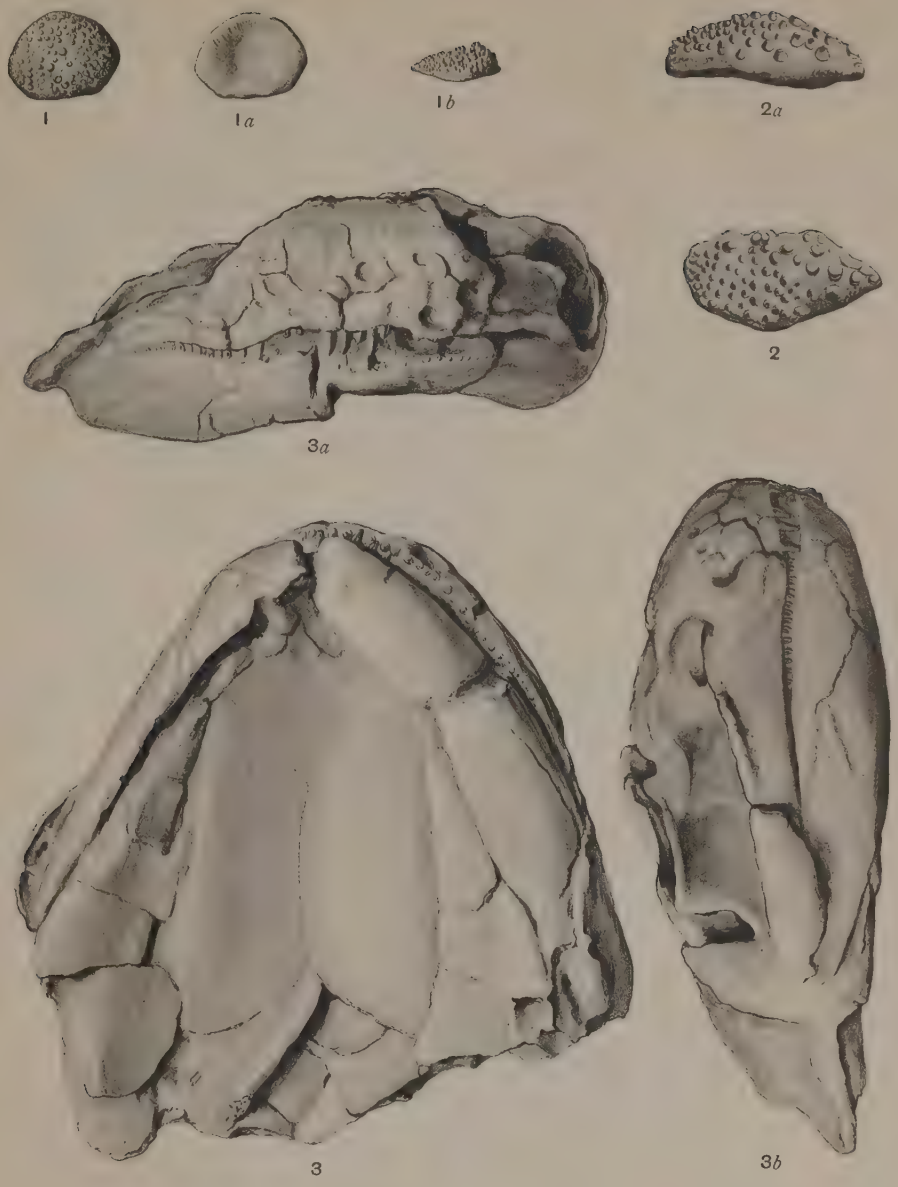
6, 6*a*. *Ctenacanthus amblyxiphias* (Cope). × 1⅓. No. 7282 Am. Mus.

7. Scale of *Platysomus palmaris* (Cope), of about three times the natural size.

8. *Diacranodus platypternus* (Cope). Posterior portion of right meckelian cartilage, in outer view. × ⅔. Cotype. Texas. No. 7243 Am. Mus.

9. *Diacranodus texensis* (Cope). Left meckelian cartilage slightly defective at posterior extremity; in outer view. × ⅔. Texas. Am. Mus.

9b. Articulating surface of the meckelian cartilage seen from above.



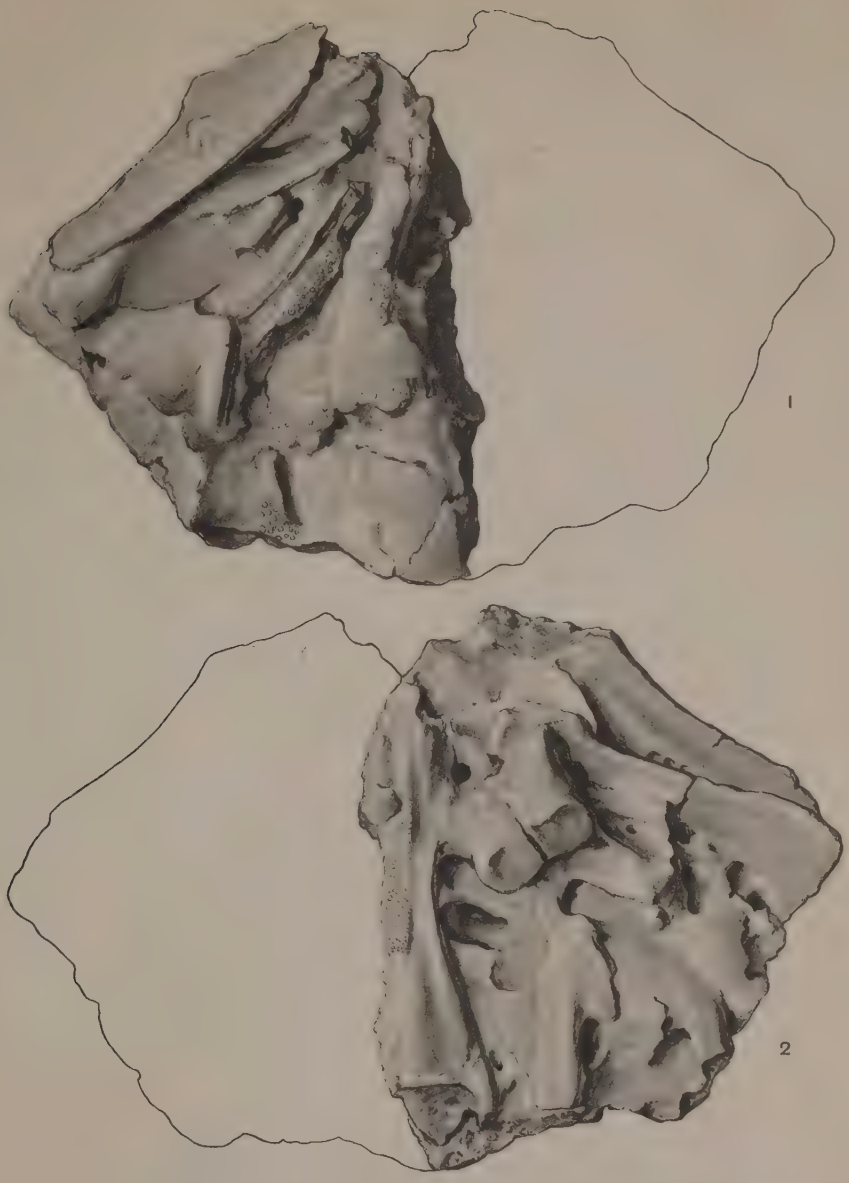
1-2*a*, *Sphærolepis arctata* (Cope).

1, 1a, 1b. Complete dentigerous plate, in upper, under, and side views, natural size. Vermilion Co., Ill. No. 6512 Univ. of Chicago,

2, 2*a*. Fragmentary dentigerous plate, in upper and side views. × 2. Type. Vermilion Co., Ill. No. 6511 Univ. of Chicago.

3-3*b*. *Megalichthys nitidus* (Cope). × ⅔.

Head of type specimen viewed from in front (fig. 3*a*), from below (fig. 3) and from the right side (fig. 3*b*). Texas. No. 7239 Am. Mus.



Spermatodus pustulosus. Type. × ⅔. No. 7245 Am. Mus.

1. Crushed skull; from above.
2. The same from below.

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